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An impression from the pen of George E. Brown, Esq., F.I.C.
Editor of "The British Journal of Photography."

# *Natural-Colour Photography*

## AT THE ST. JAMES' STUDIO, THE CORNER, 45 OLD BOND ST., W.

*Proprietors*—The Rotary Photographic Co., Ltd., London, E.C.

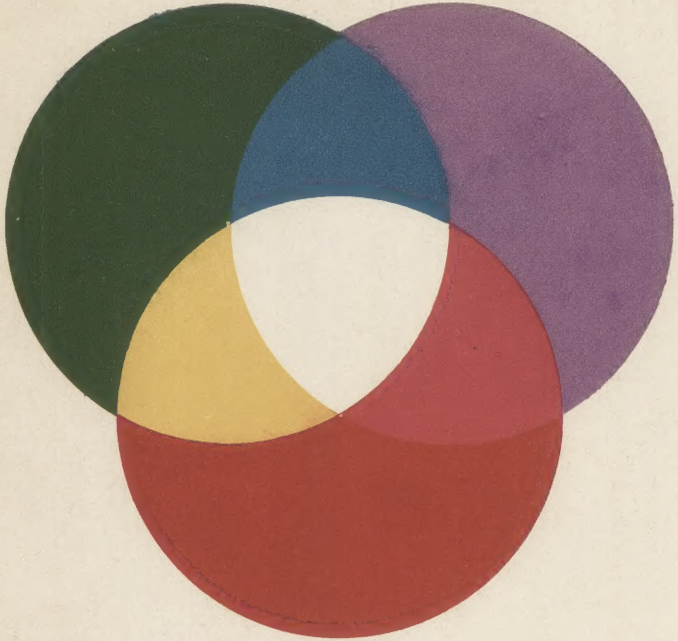
A NEW and important step is being made in colour photography by the opening in London of the first studio for regular photographic portraiture in natural colours. The occasion does not denote simply commercial enterprise. It also marks advances in colour photography, which remove it from a place among amateur pastimes and promote it to a position among the applied arts, if not among the fine arts.

The Studio, which is the scene of the new process, is in a large new building at the corner of Piccadilly and Old Bond Street. It is approached through a suite of rooms, in which is displayed a collection of examples of the process. Colour photography, it should be explained, has been practised for some years past by a few skilled amateurs, and the particular products employed in the making of portraits in colours are well known to these daring and patient workers as the "Carbon Films" of the Rotary Photographic Co. The task of the Company, however, in conducting a studio for the photography of sitters in the regular way is a far more exacting one. For a photograph in colours three negatives must be taken, and each is made through a coloured screen, blue, green or red, which obstructs a large proportion of light. Hence the difficulties of the colour-photographer in diminishing the time during which the sitter must remain still, greatly exceed those of the ordinary maker of photographs, whose work is done through an unscreened lens, and who has to obtain but one negative.

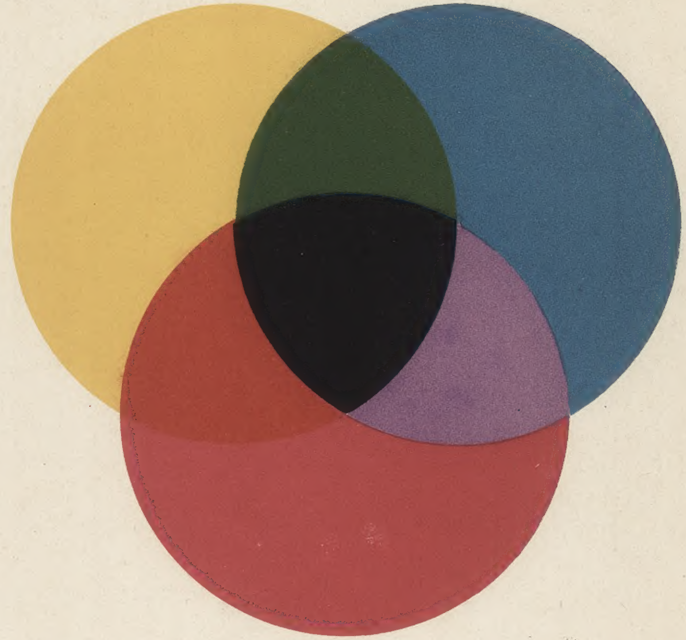
In The St. James' Studio the demands of colour photography have been satisfied by the provision of the most rapid lenses it is possible to procure, by the manufacture of coloured screens of new composition, and by the employment of new sensitive plates, which, before use, are bathed in dyes and dried, whereby their sensitiveness is many times increased. Each of these essentials to the process has involved months of research before things arrived at the stage when a sitter could be asked to seat herself before the camera. The fact that the process is now in working order, is due to the simultaneous perfection of the three factors. In the new studio this realization is seen in practice. The only difference which the non-photographic person is likely to notice is the black frame which projects from each side of the camera — the repeating back it is called — which carries the three plates. In this frame the plate-holder slides, as one exposure is dexterously made after another, whilst the sitter remains seated for a time which is very little longer than many photographers would consider necessary for an ordinary portrait. The studio is provided with arc lighting, probably the most powerful photographic installation in London, which permits of the process being carried out irrespective of time or weather.

As in ordinary photography, the negatives are but the means to an end. The colour photograph is obtained by printing from each one by a modification of the well-known carbon process. The prints from the three negatives have to be brought together on one surface, and the result is the complete portrait in colours.

The activities of the new undertaking are not to be restricted to portraiture. In fact, it seems possible that the largest part of its immediate work will be in the reproduction, in colours, of works of art, objects of vertu, and specimens from the fields of natural history, geology, mineralogy, botany, etc. In fact, the demands for work of this kind by wealthy collectors is already sufficient to keep the present staff of the Studio busy, and there seems little doubt that when the fact is realised that a speedy and certain process of real photographic reproduction of colours is available, many scientific and public bodies, as well as private collectors, will find themselves turning to the new enterprise for a record of their possessions.



Result of the Additive Combination of Three Colors (Lights).



Result of the Subtractive Combination of Three Colors (Pigments).

*Supplement to "Natural Color Photograpy."* *Dr. E. König and E. J. Wall, F.R.P.S.*

Cornish Camera Club

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916

# NATURAL-COLOR PHOTOGRAPHY

#2113

BY

DR E. KÖNIG

TRANSLATED FROM THE GERMAN, WITH ADDITIONS, ORIGINAL TESTS AND EXPERIMENTS, ETC., BY

E. J. WALL, F.R.P.S.

Author of *A Dictionary of Photography*, etc.

WITH COLOR-CHART, TEST-RESULTS, AND DIAGRAMS

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6 FARRINGDON AVENUE, E.C.

This book is not to be removed from the Studio
H. T.

# PREFACE

NEVER within the last twenty years has there been so much interest displayed by photographers generally in photography in natural colors, as at the present time. This is undoubtedly due in great measure to the advances which have been recently made in the discovery of new sensitisers, and also to the much greater attention that has been paid to the preparation of suitable light-filters, and the publication of definite formulæ for making them.

The first edition of Dr König's book was published two years ago, and this is a translation of the second edition, with some few additions on my part, which I trust will be found useful as a practical guide to the various color processes that can be adopted by amateurs and others. Photo-mechanical processes have not been included, as they entail the use of material and machinery not usually in the average photographer's outfit.

E. J. WALL.

SIDCUP, *May* 1906.

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## PART II

# NATURAL-COLOR PHOTOGRAPHY

## INTRODUCTION

The problem of photography in natural colors is almost as old as photography itself. Not satisfied with the results obtained, the followers of the black art soon wanted to fix the image projected by the lens, not only in its luminosity, but also in all the splendor of its color; and it was not long before various methods were known, which rendered possible more or less completely the preparation of photograms in color.

We shall see that the principles of color photography were discovered long ago, and that actually new discoveries have not been made for a long time. If photography in natural colors has been more to the front of late, it is not due to the discovery of a new method, but rather to improvements in known processes—so much so that now there are no insurmountable difficulties in the practice of it.

This work is intended as a practical text-book, and therefore a complete treatise on the various methods in which the problem has been attacked would be out of place; so we must confine our attention only to the most important and most interesting methods. To those who are deeply interested in the history of color photography, the following works are recommended: Eder's *Geschichte der Photographie*; *Three-Color Photography*, by Hübl; and *A Handbook to Photography in Colors*, by Bolas, Tallent, and Senior.

The methods for making photograms in natural colors fall into two classes—the direct and indirect.

## THE DIRECT PROCESS OF COLOR PHOTOGRAPHY

The direct processes of color photography seek to obtain a picture in its natural colors direct in the camera. There are three methods.

### I. Becquerel's Process

This, the oldest of all processes of color photography, is based on the fact that chloride of silver which has been darkened by exposure to white light assumes the color of any light which falls upon it.

For exposures in the camera this process is not to be thought of, on account of the length of exposure; but only for the reproduction of colored transparencies by contact printing in a frame. The pictures thus obtained cannot be fixed, the reproduction of the colors is only moderate, and the process is only of scientific value.

### II. Lippmann's Process

If a plate, coated with a transparent, or so-called grainless, panchromatic emulsion, is exposed through the glass, with the sensitive film in intimate contact with metallic mercury, the reflected rays of light interfere with the incident rays, and produce in the sensitive film fine laminæ of metallic silver, separated by half a wave-length of the light that produced them. These layers of silver appear brownish when looked through, but when examined by reflected light they reproduce perfectly the colors of objects. This process is of great scientific interest. Unfortunately, the duration of exposure, in consequence of the insensitiveness of the plates, is very long; the pictures can only be seen by reflected light, and cannot be printed from; and finally, white and mixed colors are not always well rendered, so that Lippmann's process of color photography is of no practical value.

Dr Neuhauss of Berlin, who has paid great attention to this subject, recommends the following method of making the emulsion, for which three solutions are required:—

| | | |
|---|---|---|
| 1. | Gelatine . . . . . | $38\frac{1}{2}$ grains. |
| | Distilled water . . . . | 2 ozs. 222 m. |
| 2. | Silver nitrate (cryst.) . . . | 23 grains. |
| | Distilled water . . . . | 85 minims. |
| 3. | Gelatine . . . . . | 77 grains. |
| | Distilled water . . . . | 2 oz. 300 m. |
| | Potassium bromide . . . | 23 grains. |

Allow the gelatines to soak in the water for ten minutes, and then melt by heat, and allow No. 3 solution to cool down to 95° Fahr., but No. 1 only to 99° Fahr. Add No. 2 solution to No. 1, stirring well, and in the dark room add the mixture to No. 3, drop by drop, stirring all the time. When the mixing is finished, add either of the following sensitising solutions:—

| | |
|---|---|
| 1. Alcoholic solution of crystal methyl-violet (1 per cent.) . . . | 63 minims, |

or

| | |
|---|---|
| 2. Cyanine solution (1:500 alcohol) . | 76 minims. |
| Erythrosine solution (1:500 alcohol) | 50 „ |
| Glycine red (Kinzelberger's) . . | 250 „ |

The first is strongly recommended by Professor Lippmann, and is much simpler than the latter.

The emulsion should now be filtered as quickly as possible through well-washed wash-leather, and it is then ready for coating on the glass, which must be thoroughly clean. The glass must not be too thin, and should be warmed before the emulsion is coated. Enough emulsion should be poured on the glass and flowed over its surface, and the surplus drained off, and the plate laid on a levelled marble slab or sheet of plate-glass to set. Practically, it may be said that as little emulsion as possible should be left on the glass.

When the emulsion has set, the plates should be washed under a strong stream of water for a minute, and then placed in an upright grooved rack and immersed in a tank full of clean water, and left for about fifteen minutes, the water being changed once in that time. They should then be whirled in a whirler to free them from adherent water, and then dried.

The plates are quite transparent, and it is difficult to tell which is the coated side, so that it is as well to mark the glass in some way. The exposure is made through the glass, so that this must be thoroughly cleaned.

The plate is placed in a special dark slide, glass side to the lens. The special slides are provided with a small tank or space behind the plate, which can be filled with pure mercury.

When this is admitted behind the plates, the slide may be inserted in the camera, and the exposure made.

The exposure is very long—even as much as fifteen to twenty minutes for an object in bright sunlight, with a lens working at about *f*/5.

One of the most satisfactory formulæ for the developer is Lumière's pyro-ammonia, as follows :—

| | | |
|---|---|---|
| 1. | Pyro . . . . . . . | 15 grains. |
| | Distilled water . . . . | 3 ozs. |
| 2. | Potassium bromide . . . | 150 grains. |
| | Distilled water . . . . | 3 ozs. |
| 3. | Liq. ammonia . . . . | 10 per cent. sol. |

For use, mix—

| | |
|---|---|
| No. 1 . . . . . . | $2\frac{1}{2}$ drachms. |
| No. 2 . . . . . . | $3\frac{3}{4}$ „ |
| No. 3 . . . . . . | 75 minims. |
| Water . . . . . . | $2\frac{1}{2}$ ozs. |

After development, the plates may be fixed in a 15 per cent. solution of hypo, or a 5 per cent. solution of potassium cyanide (but the latter solution must not be allowed to act longer than twenty seconds at the outside), and then well washed in running water.

On drying the plate, the colors should appear; but they can frequently be rendered more brilliant by bleaching in mercuric chloride solution, 2 grains to 1 ounce, then washing, and blackening with amidol developer.

In order to avoid surface reflections, a shallow prism should be cemented to the face of the result by means of Canada balsam, and the back of the plate should be coated with black varnish.

Possibly a brief explanation of the formation of the colors is desirable. In fig. 1, in which everything is grossly exaggerated and out of proportion, P represents the glass, and M the mercury, with the sensitive film between. Three rays of incident light proceed from the lens. R we will assume to be red light of wave-length 670 ; G, to be green light of wave-

length 520; and B, blue light of wave-length 400. Then the light reflected from the mercury passes through the film exactly on the path of the incident ray, and interferes with the same. Where the rays cross there is no light, and consequently no action on the silver salt; so that the latter is only acted upon at every half wave-length, and the distance apart of the laminæ of silver thus formed is exactly half the wave-lengths stated above—thus, for the red, 1340; for the green, 1040; and for the blue, 800.

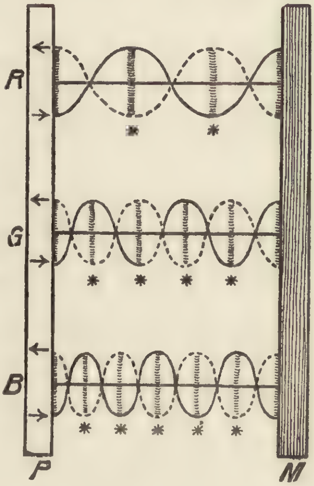

Fig. 1.

Quite recently plates for this process have been placed on the market by Kranseder & Co., of Munich.

## III. The Bleaching-out Process

This interesting process is based on the fact that unstable dyes are destroyed or bleached only by those rays of light which they absorb. Thus, an unstable red dye will be stable in red light, but will bleach out in any other colored light. This striking phenomenon was first explained by Herschel, and is easily understood, if one grasps the fact that only those rays of light which are absorbed by a dye, and not those which are reflected, can exert their energy in chemical decomposition of the dye. If colored light falls on a film which contains a mixture of properly chosen yellow, red, and blue dyes, and which has a blackish appearance, only the dyes will be destroyed which absorb the colored rays of light. For instance, yellow light will bleach the red and blue pigments, and leave the yellow. Worel[1] of Graz, Dr Neuhauss[2] of Berlin, and Szczepanik of Vienna[3] have

[1] Eder's *Jahrbuch*, vol. xvii. p. 68; vol. xviii. p. 42; vol. xix. p. 7.

[2] *Ibid.*, vol. xvi. p. 20; vol. xvii. p. 47; vol. xviii. p. 62; vol. xix. p. 51.

[3] Szczepanik's or a similar tissue is now commercially prepared by Dr J. H. Smith & Co. of Zurich.

chiefly experimented with this process. Unfortunately, the sensitiveness of this process is so little that camera exposures are impossible; it is only suitable for the production of prints true to color by printing from colored transparencies in a printing-frame.[1]

The process is not a difficult one, and Neuhauss gives the following directions for preparing the sensitive film:—

| | |
|---|---|
| Gelatine . . . . . | 154 grains. |
| Distilled water . . . . | $3\frac{1}{2}$ ozs. |

Soak the gelatine for half an hour, and melt by the aid of a water-bath, and then make the following dye solutions:—

| | | |
|---|---|---|
| 1. | Methylene blue . . . . | $1\frac{1}{2}$ grains. |
| | Distilled water . . . . | $1\frac{3}{4}$ ozs. |
| 2. | Auramine . . . . . | $1\frac{1}{2}$ grains. |
| | Alcohol. . . . . . | $1\frac{3}{4}$ ozs. |
| 3. | Erythrosine . . . . . | 4 grains. |
| | Distilled water . . . . | $1\frac{3}{4}$ ozs. |

To the above quantity of gelatine solution add—

| | |
|---|---|
| No. 1 solution . . . . | 68 minims |
| No. 2 " . . . . | 34 " |

and stir well, and add almost drop by drop, with continual stirring,

| | |
|---|---|
| No. 3 solution . . | about 25 minims. |

Only enough of this should be added, and on the slightest sign of a reddish tinge it must be stopped. This mixture should be kept for three or four hours at a temperature of from 95° to 110° Fahr., and then should be added to the above quantity—

| | |
|---|---|
| Chloral hydrate . . . . | 31 grains, |
| Caustic soda solution 30% . . | 10 drops, |

and the mixture coated on paper or opal glass.

It may be noted that Szczepanik coats his films one on top of the other, and uses red, green, and a blue-violet.

[1] Since this was written, Dr J. H. Smith of Zurich has greatly increased the sensitiveness of the process, and has hopes of making a bleach-out film sufficiently sensitive for camera exposures.

## IV. Joly's or M'Donough's Process

We must mention here Joly's process, which was first suggested by Ducos du Hauron in 1868, as being to some extent intermediate to the indirect processes of color photography, all of which are based on the splitting up of all colors into the three fundamental color negatives—yellow, red, and blue. This was almost simultaneously re-invented and rendered practical by Dr John Joly, in Dublin, and M'Donough, in America. Joly placed, during exposure, before a panchromatic plate, a sheet of glass ruled with fine parallel transparent lines of red, green, and blue. The colored lines act as light-filters or screens—that is to say, the red lines practically transmit only red, the green only green, and the blue only blue light. If the plate is, for instance, struck by green rays, it will only be blackened, on development, under the green lines, and so on. The result is a negative consisting more or less of bright and dark lines. If, now, from this negative a transparency be made, and on this a plate, ruled similarly to the negative taking-screen, be laid in its proper position, a colored image consisting of fine lines will be obtained. This colored image is due to the fact that the colored lines of the screen are visible through the clear lines of the transparency, but covered by the opaque lines. The chief defects of this process are: (1) that the image is not homogeneous, but consists of colored lines, and has therefore a somewhat irritating effect; (2) the ruled screens were dear, which is all the more important since each transparency requires a screen.

Powrie of Chicago has recently announced a modification of the manufacture of such plates which promises well. He says:[1] "Sheets of ordinary negative glass are coated with bichromated gelatine, and exposed to the light through a negative plate of transparent and opaque parallel lines. The light passing through the transparent lines of the negative renders the gelatine insoluble in warm water, the unexposed portions washing away, thus securing upon the glass colorless gelatine lines, which, with the plates now in use, are from $\frac{1}{600}$ to $\frac{1}{1000}$ of an inch in width.

[1] *Penrose's Pictorial Annual*, 1905–6, p. 111.

"The plate is then immersed in a color bath of a suitable green dye, and then in subsequent baths to render the color stable, washed and dried. The appearance of the glass is a delicate green tint. It is then recoated over its entire surface with bichromated gelatine, and again exposed to the light through the opaque-lined negative, taking the precaution to have the green lines protected by the opaque lines of the negative, and also one-half of the remaining unexposed surface.

"The plate is treated in a similar manner after this exposure as for the green lines, except that a red dye is now used, and the plate is rinsed and dried as before. The appearance of the plate is yellowish in tone. It is then coated a third time, again exposed, and passed into a bath of violet-blue dye. This gives the plate a neutral tint, from the recomposition of the three elementary colors, the surface being completely covered without overlapping of the edges.

"It is possible by this photographic printing operation, with special machinery for aligning the plates and printing them automatically, to obtain remarkable uniformity. The increased fineness of the color lines renders them invisible to the eye, and registration of the lines with a transparency would be impracticable.

"The next operation is that of coating them with a panchromatic emulsion, when they are ready to be exposed in an ordinary camera, developing and fixing in the usual manner, and obtaining a negative in colors. It is obvious that in this case the exposure must be made through the glass. These negatives show the red rose as green, the green grass appears purple, yellow flowers appear violet, and violet appears yellow, the colors, as well as the lights and shades, being reversed.

"In order to understand this, I should explain that light reflected from a red object passes through the red lines in the chromatic plates, the red rays being absorbed by both the green and the violet-blue lines; and on development and fixation it is found the silver is deposited only upon the red lines, leaving the green and blue lines transparent over the particular area representing the red object, giving it a greenish-blue color.

"By the use of chromatic transparency plates and films,

lantern slides and window transparencies may be made in the ordinary way, either by contact printing, reduction or enlargement in the camera, no regard to registration being necessary, as the lines are practically disregarded in this process, being merely a convenience for the manufacture of the plates only. The transparency plates differ from the negatives only in the use of a transparency emulsion upon the lined plates, which is also panchromatic."

The plates made by this process are to be known as Florence plates.

### V. Lumière's Starch Grain Process

Whilst Joly, M'Donough, and Powrie used a screen consisting of a series of lines, the brothers Lumière in their new process employ a grained screen which is prepared in a particular manner from potato starch grains. From the potato starch the granules are sifted out which have a diameter of 0·015–0·020 millimetre, separated, and then dyed in three lots—red, green, and blue. The colored powders thus obtained are mixed so that no one color predominates, and the mixture is spread on a sheet of glass, which is coated with a sticky substance, by means of a soft brush. By this means all the colored grains should touch, but should not overlap. The spaces, which must necessarily occur between the round granules, are filled up with lamp or other black, and the whole coated with a varnish. On the plates thus prepared a panchromatic gelatino-bromide emulsion is coated, and the plates exposed in the camera through the glass. The colored grains in this process act in precisely the same way as the colored lines in Joly's process, namely, as light-filters, and the result after development and fixing is a negative, which, when looked through, shows the complementary colors of the subject photographed. By printing from such a negative on to a plate prepared in a similar way, a transparency is obtained in the correct colors. If, after developing the negative, without fixation, the metallic silver is dissolved, and the silver bromide that is left is again exposed and developed, it would be possible to obtain a direct positive in the correct colors.

Although, after this description, the preparation of the

plates appears very difficult, they will be shortly on the market.

It is obvious from these short explanations that the direct and simplest methods of color photography are not of much practical value, and the practical worker must therefore turn his attention to the somewhat more troublesome indirect methods.

Professor R. W. Wood of Wisconsin, U.S.A., devised in 1899 a method of producing pictures in their natural colors by optical synthesis, by means of three diffraction gratings ruled in different degrees of fineness on glass. Three constituent negatives are taken in the ordinary way through the usual red, green, and violet filters, and from these transparencies made by the usual photographic process. A sheet of glass is coated with bichromated gelatine and dried, and exposed to the transparency taken through the red filter, the coarsest ruled diffraction grating being placed in between; the whole is then exposed to sunlight, using parallel rays as far as possible. On the same plate is placed the positive from the negative taken through the green filter, with a finer filter interposed, and again exposed to sunlight, and the plate then developed with warm water. The third transparency, from the negative taken through the violet filter, is exposed, film side out, with a second bichromated gelatine plate, a still finer ruled grating being interposed, and then developed with warm water and dried. On bringing the two plates into accurate register and viewing them by transmitted light by means of an eye-piece, a picture in colors will be seen, the colors being formed by the decomposition of the light by those lines of the various diffraction gratings which were impressed on the bichromated gelatine, through the transparent parts of the positives used.

In 1904 Professor Wood improved his process and applied it to positives obtained by the Joly process—that is, positives obtained from the negatives taken through screens ruled with the three filters in closely contiguous lines. Gratings were ruled with three sets of lines in bands corresponding to the width of the red, green, and blue lines of the Joly screen. The positives from the Joly negatives were flowed with a thin solution of gelatine sensitised with bichromate of potash, and dried. The triple ruled grating was then placed with

its ruled surface in contact with the sensitive film, and exposed for a short time to light, and the plate then dipped in warm water and dried. The effects obtained in this way are, it is stated, equal, if not superior, to those obtained with the Joly viewing screen, with the added advantage that the color lines and picture lines are on one and the same film; consequently there is no liability of the lines to get out of order. Such pictures can be duplicated by contact-printing on glass sensitised with bichromated gelatine.

## THE INDIRECT METHODS OF COLOR PHOTOGRAPHY

The indirect processes consist, as already mentioned, in the splitting up of the image into three fundamental colors, and in the synthesis of the colored picture by three primary colors. For this reason the indirect methods are generally called three-color or trichromatic photography.

The honor of having first enunciated the above-mentioned theory belongs to the renowned English physicist, Clerk-Maxwell, in 1861.

Somewhat later, the well-known French experimenters, Ducos du Hauron and Cros, attempted to carry this principle into practice. Unfortunately, they could only carry out their ideas in a very incomplete manner, as the means they had at their command were insufficient. Since Ducos du Hauron's time, as a matter of fact, there has been scarcely anything actually new discovered; and notwithstanding the frequent occurrence of sensational statements in the lay and technical press, one may be pretty well sure that in the best cases there is merely an improvement in the old three-color process.

Though our modern processes can always be ascribed to the old principles, it would be erroneous to assume that we have not advanced. The technique has, in the last few years, been perfected to an extraordinary degree. Chemistry has given us not only suitable brilliant dyes for staining and printing the pictures, but also numerous sensitisers which enable us to sensitise bromide of silver, which is only sensitive to blue, for any region of the spectrum.

Opticians have placed upon the market new objectives of

larger aperture, specially constructed for color photography. Camera-makers have constructed very convenient and comparatively simple apparatus: so that, as a matter of fact, color photography presents to-day no difficulties to anyone versed in monochrome photography. Undoubtedly photography in colors is more trouble—and it will always be—than ordinary photography. It requires more skill, experience, and a certain knowledge of the fundamental principles on which trichromatic photography is based. Whoever takes up color photography without being quite clear why any operation which he performs is done exactly so, and not otherwise, can only obtain satisfactory results by accident. Slavishly working from given formulæ is the least satisfactory of all methods. There is, however, rich reward for the unavoidable trouble. Whoever has seen the brilliant colored pictures by MM. Lumière, whoever has looked into a kromskop or seen good pictures by triple projection, will, with these in mind, willingly take the trouble and care necessary to attain a similar result.

# PART I

## THREE-COLOR PRINTING, OR THE SUBTRACTIVE METHOD OF THREE-COLOR PHOTOGRAPHY

Three-color photography is based on the principle that all colors occurring in nature can be split up into three primary or fundamental colors—red, green (or yellow), and blue—and can be formed again from these. If the image of a colored object is split up photographically into three constituent images, of which the one reproduces only the yellow, another only the red, and the third only the blue parts, these monochromes will, if properly superimposed, give a representation of the object true to nature.

To split up the image into the three primary colors, light-filters or color-screens are used, which may be either dry or liquid filters. The latter consist of parallel-sided glass cells which can be filled with a suitable dye solution; the former consist of well-polished glass plates coated with stained gelatine or collodion. Glass filters colored in the mass are unsatisfactory, for it is extremely difficult, if not actually impossible, to so color glass flux that it shall satisfy the requirements of color photography.

If in the path of the rays of light which form the image on the plate a blue filter is inserted, it transmits all rays of light except yellow, so that all the rays of light will produce an image on the plate except the yellow. In other words: the negative when developed will have the red and blue represented by a deposit, but the yellow, or any color containing yellow, will be represented by more or less bare glass. If this negative be now printed from on a film of bichromated gelatine colored yellow, or if this is afterwards stained yellow, an image will be obtained which will only reproduce the yellow parts of the original: *this will be the yellow print.*

The procedure is exactly the same to obtain the red constituent print. During exposure a green filter, which only transmits green, blue, and yellow, and absorbs red, is used. In the negative thus obtained green, blue, and yellow will be represented by a deposit, and red be clear glass. In printing on a red-stained bichromated gelatine film we shall obtain *the red print.*

Finally, to obtain the blue constituent print, an exposure is made behind an orange filter, which transmits red and yellow and absorbs blue. The negative will show the red and yellow dense and the blue clear glass; this negative, when printed on blue-stained bichromated gelatine, will give *the blue print.*

This is, in a few lines, the theoretical basis of three-color photography.

## I. THE APPARATUS

Any good, firm stand-camera may be used for color work; and even hand-cameras in which the plates can be easily, and with certainty, changed without movement of the camera itself may also be used. As a rule, larger than quarter or 5 × 4 plates will not be used, and larger pictures should be made by enlarging the small original negatives.

Since, as already pointed out, three exposures have to be made of the same subject, and the outlines of the images must absolutely coincide, a firm and solid stand is one of the main essentials.

The light-filters may be placed in different positions:

1. Immediately in front of the lens.
2. Between the lenses, at the diaphragm plane.
3. Immediately behind the lens.
4. Immediately in front of the plate.

The first position, which is very convenient, can only be recommended when absolutely parallel and optically worked glasses, which are of course very dear, are used for the filters. If inferior glasses are used, the definition of the image suffers considerably.

For the same reason the second position cannot be recommended. The filters to be used close to the diaphragms must necessarily be extremely thin and easily broken, and

must be either glass or merely collodion films, and readily cause enormous distortion of the image.

The third position, immediately behind the lens, is better; still, even in this position, with lenses of long focus, the sharpness of definition may be easily destroyed, if the filter is not made of optically worked glass.

As a rule, the ordinary patent plate of commerce is satisfactory. For those who do not wish to set aside, or procure, a special camera for three-color work, the last-named method of using the filter will be the most convenient. The filters, which need be very little larger than the diameter of the lens, can be fitted by means of springs inside the lens-board of the camera. Changing the filters, when in this position, naturally leads to loss of time. A capital plan is to fasten the filters to wires, which can be manipulated from the outside of the camera. The three filters may also be arranged in a sliding frame just behind the lens, and this can be worked from the outside, and the filters changed by merely pushing the frame along.

With cheap outfits the dark slides are not so exactly made that they can be depended upon for color photography. It is advisable to test whether the three images obtained with different slides absolutely coincide, and to choose only those slides which are perfect.

For flower or still-life subjects the above-described arrangements will be quite satisfactory. For the majority of cases, and especially for the more advanced workers, direct landscapes and portraits will offer the most enticing charms. These cannot be tackled so well with the above-described means, as the change of filters and dark slides will take up too much time—more even than the actual exposures themselves.

The fourth position of the filter, mentioned above—namely, close to the plate—is from the optical point of view that which can be most recommended. When placed immediately in front of the plate the filter hardly detracts from the definition of the image, even if it is made of common glass; for any defects in the glass only destroy definition on those parts of the plate immediately behind the defect, and do not cause general fuzziness of the whole of the image.

The filters can be very easily fitted in many hand-cameras, if extra-deep sheaths are used, in which plate and filter can

be fitted together. The filter should then be placed in contact with the sensitive film. In focussing, care must naturally be taken to rack back the ground glass the thickness of the filter.

Recently there have been introduced the so-called Flexoid filters, made of sheets of flexible gelatine, which are so thin that they can be placed in front of the plate in every dark slide without interfering with the focus. These filters are not so practical nor so cheap as they might at first sight appear to be, as they easily cockle under the action of damp, matt places are caused by contact with the fingers, and they are mostly very brittle.

The Vidil films which are made for three-color work are provided alternately before each individual film with blue, green, and red sheets of gelatine, which are unrolled and rolled up with the sensitive film. It is without doubt very difficult always to make these films so even and exact as is necessary for three-color photography.

Apparatus specially constructed for three-color work is already commercially obtainable. In all cases the filters are placed immediately in front of the plate. The least commendable of all these are those with horizontal sliding frames. A very efficient three-color camera from the designs of Dr Miethe is made by Bermpohl of Berlin. The filters are fastened in a wooden frame, and immediately behind them are the dark slides; the filter frame and slides can be easily moved down in a vertical direction, so that one filter after the other appears in the plane of the focussing screen. Recently this apparatus has been fitted with a pneumatic attachment which facilitates the changing of the filters.

Another apparatus, which has the further advantage that it can be used for ordinary work, is the Pinatype camera, sold by Fuerst Bros. This is of the well-known folding form. The plates are carried in very thin metal dark slides behind the filters, which are fitted in a metal sliding frame; and before exposure all three slides are drawn, and the sliding movement, which is in the vertical direction, is effected by a pneumatic release. Both cameras have given us excellent results.

In France, the Société de Photochromie of Paris have

placed on the market a one-lens hand-camera for color work. Sanger-Shepherd & Co. also make a one-exposure camera.

As the plates are unprotected in these cameras, it is obvious that a shutter must be used which can be set without opening—that is, a so-called "ever-set" shutter must be used.

The ideal trichromatic camera would naturally be one in which only one exposure is required. Obviously it is impossible to work with three lenses, for the images would never coincide. In the construction of such an apparatus, therefore, recourse must be had to the projection of the image, produced by one lens, by means of mirrors or prisms through the three filters. The exposure must then be as long as is necessary for the red filter, and the green and blue filters must be so made that the necessary proportion of light reaches the other plates; or the use of stops must be called into play. Such apparatus for the taking of all three pictures at once is necessarily, on account of its complicated make, extremely costly.

Recently Perscheid of Berlin has patented a three-color camera in which the exposure of the three plates is automatically effected by clockwork, which can be previously set accurately for all three exposures, and can be set going without vibration by touching a lever. The three exposures are then very exactly made without any further attention on the part of the operator. In portraiture it is doubtless an advantage not to have the sitter disturbed by any manipulations of the camera. According to the patent specification, the duration of the exposures may be fixed to the hundredth part of a second. It is easy to believe that the clockwork may effect these exposures accurately, but where is the photographer who can reckon the exposures to a hundredth of a second? It would be a bad thing for color photography if one were bound down to such exactitude.

As rapid a lens as possible should be used, one with at least an aperture of *f*/8: the modern lenses of the best opticians are all of them applicable, especially those of the most rapid types with a ratio aperture of *f*/4–*f*/5. It must not be forgotten, however, that the depth of focus of these lenses is naturally very little, and therefore, except for portraits, they can rarely be used at full aperture. It is also advisable not to

have too long a focus lens, so that greater depth can be thus obtained also: for $5 \times 4$ and quarter-plate pictures lenses of from 4 to 6-inch focus are the most suitable. When working with small-sized plates and short-focus lenses, it is not necessary to use lenses specially corrected for color photography; any good achromatic objective will suffice, and therefore the cheaper and older aplanats will produce good color photograms.

If larger pictures than $7\frac{1}{2} \times 5$ inches are required, it is far better to enlarge small negatives, as has already been stated, than to make direct exposures on large plates; and for this work the commercial daylight enlarging apparatus, which is arranged only to give one-sized enlargement with a fixed focus, is specially satisfactory, for one can be quite sure that the enlarged negative will always be quite sharp. The sharpest enlargements are obtained by making enlarged transparencies from the original negatives and making negatives from these by contact.

Of the various processes which may be used for this, Pinatype offers special advantages for making enlarged pictures, as will be seen later on.

For trichromatic stereoscopic work the same rules obviously apply as for ordinary stereo work. Still-life subjects can be satisfactorily tackled without a stereoscopic camera if an ordinary camera be used, and either one of the usual stereo adapters be used, or the camera be shifted sideways and the exposures kept absolutely the same.

C. J. Drac has patented a camera which is provided with a lens behind which is mounted a direct-vision prism, by which the image is split up into a spectrum. In the plane in which this spectrum is formed are two prisms, separated by a space, which is adjustable, so that any portion of the centre of the spectrum can pass directly to a second series of lenses, whilst the prisms at either side deflect the outer portions of the spectrum, producing thus three parallel beams of light which form their respective images, by the aid of the second series of lenses, on one plane. The instrument is reversible, and if, instead of the ground glass, a triple transparency be inserted, this may be viewed directly through the lens or projected. The analysis and synthesis of the light is thus performed without the aid of filters. The negatives

obtained by this instrument can, of course, be printed in the complementary dyes in the usual way.

### The Filters

We now come to the preparation of the filters, the most important part of the three-color outfit. They may be obtained commercially; still, it is advisable only to purchase them from recognised expert sources. As the filters (the preparation of which requires great care) are very dear, many have wished for accurate formulæ for the preparation of the same, and many such formulæ have been published, but their value is very doubtful. Most of the authors of these filter formulæ are not sufficiently acquainted with the chemistry of coal-tar dyes, and they mix together those which optically appear to be convenient, without consideration of their chemical properties. If, for instance, basic and acid dyes are mixed together, as is prescribed in dozens of formulæ, one ought not to be surprised that the mixtures give streaks and scum, or coagulation and precipitates are caused. It is also very obvious to any expert that when the ordinary commercial dyes are used, all sorts of irregularities, such as roughness, granularity, or crystallisations, may occur during the drying of the gelatine. Almost all the commercial aniline dyes contain the diluents which are required in the ordinary processes of dyeing, such as salt, sulphate of soda, dextrine, sugar, and so on; and the removal of these impurities can only be effected with great difficulty. The same dye is frequently placed on the market in different strengths, and the products of the various factories are not always the same, so that the formulæ which have been published only apply to the actual dyes which the author actually used.

The filters or color-screens can be prepared in one of two ways: either by bathing gelatinised glass plates in solutions of the dyes, or by coating glass with stained gelatine. In the first case it is naturally not necessary to use chemically pure dyes; but exact formulæ for the preparation of the filters cannot also be given, and the progress of staining must be controlled with a spectroscope, so as to stop it at the right moment.

The more accurate method is undoubtedly coating the glass with colored gelatine. Obviously, for this process only

chemically pure dyes can be used, and with these all the difficulties which most authors describe are avoided. Precise formulæ can naturally also only be given for chemically pure dyes, and not for the ordinary commercial dyes, which vary in quality. On the author's suggestion, Meister, Lucius & Bruning, of the Hoechst Color Works, have prepared suitable dyes, which are specially pure, for photographic purposes, and which can be obtained in small quantities.

From the innumerable number of dyes which from their optical properties are specially suitable for color-screens, only those have been chosen which can be easily obtained in a chemically pure state. This last fact specially applies to those dyes given in the following formulæ.

After these introductory remarks, which were absolutely necessary, as these points have hitherto never been sufficiently insisted on, we can proceed to the preparation of filters.

The first thing required is well-polished and thin (from $\frac{1}{25}$ to $\frac{1}{12}$ inch thickness) plate-glass, free from bubbles. This should be cleaned in diluted hydrochloric acid, well washed with water, and then polished, when dry, with a pad of linen dipped in alcohol and ammonia. The clean and well-dusted glass plates should be placed on a large sheet of thick glass (that from a large printing-frame can be used), which has been previously carefully levelled. On every 16 square inches (100 qcm.) should be poured 118 minims (7 c.cm.) of the colored gelatines described below. The solution should be spread quickly over the glass with a thin glass rod, one end of which should be bent at right angles; but care must be taken not to touch the film when it has once begun to set. Air-bubbles can be easily removed by touching them with a damp finger. Before coating the plates should be slightly warmed, and the room in which the coating is done should not be too cold so that the gelatine sets too quickly. On the other hand, it should not be too warm, otherwise the gelatine will not set: from 60° to 70° Fahrenheit is the best temperature. When thoroughly set, the plates should be placed in a drying-rack and dried in a place free from dust. In damp weather a drying-box should be used, and in this a dish containing anhydrous calcium chloride should be also placed. Quicklime is less suitable for the purpose, as the calcium hydrate formed is very powdery and readily flies about.

More plates than are actually required should always be coated, as in consequence of dust-spots and other accidents some are always failures. These failures can be easily washed off with warm water and used again. If there are any faint streaks visible when the filters are dry, they can be disregarded, as they mostly disappear in the subsequent cementing with Canada balsam. Much more important are irregularities in the thickness of the film, so that the film is of unequal intensity. For this reason it is not advisable to make the filter out of one glass coated with the colored gelatine and a plain glass. It is much safer to use two glasses coated with stained gelatine and to cement them together, for by this means any possible irregularities can be more easily equalised.

The cementing of the plates is performed in the following manner:—The plates to be cemented should be gently warmed over a flame, the gelatine side dusted, and then in the middle of one should be poured a pool, not too small, of Canada balsam (the Canada balsam purified for microscopy by Merck of Darmstadt), taking care that air-bubbles are not formed. Then the second plate should be placed (film side down, of course) on the edge of the first, and then gently lowered and pressure applied, avoiding as far as possible the formation of air-bubbles; should, however, a few bubbles occur, they may be removed by strong pressure of the fingers, and in obstinate cases gently warming.

Any excess of the balsam which exudes may be scraped off with a knife; and if any quantity of this be collected, it can be mixed with a little xylol or toluol, filtered, and again used.

When the cementing is properly done and there are no air-bubbles showing, the filter should be placed on a sheet of paper on a levelled glass plate and a weight placed on the top. For a quarter-plate screen, this should first be a quarter-pound, and later, say after twenty-four hours, a two-pound weight. The glasses are rather apt to slip, so that small weights or other convenient blocks should be placed at the four corners to prevent them slipping askew.

The recommendation to place the filters on a sheet of paper is made because otherwise, if they were placed on the bare glass, the balsam that exudes under the weight would cement them so firmly to the glass that it would be almost

impossible to remove them. It is as well to dry the filters in a warm place. Finally, the firmly cemented filters should be cleaned with benzole or turpentine, then polished with alcohol and ammonia, and finally bound round with strips of paper or cloth similarly to lantern slides.

The filters should not be unduly exposed to sunlight or bright daylight, as the colors may fade: if this precaution is observed, the filters will last for years, perhaps indefinitely.

### Formulæ for the Stained Gelatine

We have remarked already more than once that the following formulæ, which have been most carefully tested, do not apply to any commercial dyes of the same name, but only to those manufactured specially for this purpose.

As the basis for all the filters we use a 6 per cent. solution of gelatine, which is prepared as follows:—1 ounce of hard emulsion gelatine is allowed to soak for an hour or two in cold water and the latter drained off. The swollen sheets of gelatine are then placed in a tared glass vessel and sufficient distilled water added to make the whole (gelatine plus water) weigh 16⅔ ounces. The whole should then be carefully heated till perfect solution is obtained.

The quantities of the dyes required are extremely small; it is not possible to accurately weigh out the correct quantities of the dry dyes: we dissolve, therefore, a larger quantity of the dyes in a given quantity of water, and use an aliquot quantity of the solution to stain the gelatine.

The gelatine solution, mixed with the necessary quantity of dye solution, is carefully filtered through a dampened filter, and to every 16 sq. ins. (100 qcm.) of glass surface, as already stated, 118 minims (7 c.cm.) are allowed.

Two plates coated with this quantity are required for each filter. If it is thought desirable to coat only one glass, then naturally double the quantity of dye, or dyed gelatine, must be used.

### I. The Blue Filter

The stock dye solution consists of—

| | | |
|---|---|---|
| Crystal violet . . . | 31 grains, | 2 g. |
| Distilled water . . . | 840 minims, | 50 ccm. |
| Glacial acetic acid . . | 5–6 drops. | |

Dissolve by the aid of a gentle heat.

To every 100 parts of the gelatine solution, the preparation of which has already been described, add 7–8 parts of the above stock dye solution.

The filter whilst wet is reddish violet, but becomes much bluer on drying. This filter absorbs the yellow and green, but transmits violet, blue, and red. In case of necessity this filter may be used with an ordinary as well as a panchromatic plate.

### II. The Green Filter

The preparation of a good green filter which shall give correct damping of the blue and yellow is a much more delicate matter.

Almost all green and blue dyes—and the latter mixed with yellow give green—transmit the extreme red. As, now, the purpose of the green filter is to absorb the red, many writers have stated that a green filter which lets through the extreme red is useless. But this is not correct, for our modern panchromatic plates are so slightly sensitive to this extreme red that it is only in enormously long exposures that it could act at all. If by any chance good sensitisers for red of that extremely small wave-length should be discovered, then we are fortunate in having in naphthol green a dye which absorbs this extreme red. Nervous or timid operators may even now add naphthol green to their filters, but they must then increase the exposure. The filter described below is suitable for orthochrom plates.

*Stock dye solution.*

| | | |
|---|---|---|
| Patent blue . . . | $92\frac{1}{2}$ grains, | 6 g. |
| Tartrazine . . . | $46\frac{1}{4}$ ,, | 3 g. |
| Distilled water . . | 11 ozs. 5 drms., | 330 c.cs. |

Dissolve by the aid of a gentle heat, and add 5 parts of this solution to 100 parts of the 6 per cent. gelatine solution described above.

This green filter transmits the green, and strongly damps the blue and yellow, so that the green acts better.

Orange and red are absorbed up to the extreme red of the spectrum. That this red is harmless has already been pointed

out; but if it is considered desirable to cut this out, then the following should be used:—

| | | |
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| New filter green I. (Hoechst) | 62 grains, | 4 g. |
| Distilled water . . . | 4 oz. 107 m., | 120 c.cs. |

and add 5–6 parts of this to every 100 parts of the 6 per cent. gelatine solution.

### III. The Red Filter

*Stock dye solution.*

| | | |
|---|---|---|
| Filter red I. (dianil red) . | 77 grains, | 5 g. |
| Distilled water . . . | 7 ozs., | 200 c.cs. |

Dissolve by the aid of a gentle heat, and add 4 parts of this solution to 100 parts of the 6 per cent. solution of gelatine.

This filter transmits red, yellow, and yellowish green, and absorbs blue, violet, and a part of green. It is not advisable to use orange-red filters, which transmit more green. These filters require a shorter exposure, but the reds are not sufficiently reproduced with short exposures.

Besides the above-described gelatine filters, dry collodion filters may be used, but for various reasons the authors cannot recommend these. In the first place, the choice of dyes for staining collodion is not very great. Further, the stained collodion cannot be coated of a given thickness like gelatine, for to obtain an even coating with collodion it must be flowed over the plate and the excess drained off. Thus the intensity of the stained film is naturally to a great extent dependent on the viscosity of the collodion that is used, so that it appears quite impossible to give exact formulæ for the preparation of dry collodion filters.

We do not propose to deal with liquid filters, for they are very inconvenient, and only suitable for photo-mechanical work, and are also very costly.

Under the name of "rapid light-filters," quite recently the Hoechst Dye Works have placed on the market a series of filters which are prepared with dyes of special transparency and extraordinary absorption powers. These filters permit of a very great reduction of the times of exposure. The blue filter corresponds to that described above: the green and red filters are, however, prepared from much purer dyes than those described above. The green filter allows the red of the

extreme end of the spectrum to pass, but this red is quite harmless when pinachrome-bathed plates are used.

### The Plates

Opinions are much divided as to the plates that should be used. Whilst some consider that a panchromatic plate—that is, one sensitive to all colors—only should be used for all three exposures, others recommend a plate specially sensitised, and corresponding to each filter ; thus three kinds of plates should be used.

The first method, that of working with one plate, has the advantage that the negatives obtained are alike in character and gradation. A disadvantage is that small faults in the filters are of much more moment than when one uses a specially sensitised plate behind each filter. An example will make this clear. If the green filter passes any of the orange-red, this will be very troublesome if we use a panchromatic plate—that is, one sensitive to red. If, however, a plate is used which is only sensitive to that part of the spectrum which is transmitted by the green filter—thus, to green, yellow and blue—the red which the defective filter passes will do no harm, as the plate is not sensitive to red.

The second method of working, with three different kinds of plates, has on the other hand the disadvantage that the three constituent negatives may be quite unequal in character, even if the same mother emulsion be used. By the addition of the sensitising dyes the gradation of most plates is considerably altered. This is still more the case when the plates are sensitised by bathing in dye solutions.

Thus erythrosine, which sensitises for yellow and yellowish green, very easily gives hard negatives ; whilst cyanine, which sensitises for yellow and red, gives very flat negatives. Different sensitisers which belong to the same class of chemical dyes behave absolutely alike, as we shall see later on.

For working with three plates, one may use—

1. An ordinary and not orthochromatic plate behind the blue filter.
2. A so-called orthochromatic—that is, a commercial yellow-green—plate behind the green filter.

3. A red and yellow sensitive plate behind the red filter: for these, plates sensitised with pinachrome or pinacyanol are the best, and these will be dealt with later.

With regard to the orthochromatic plates mentioned in the second paragraph above, many of the commercial ortho plates are so little sensitive to yellow and green that they are quite useless for trichromatic work, and very dark filters which inordinately prolong the exposure must be used with them.

The green filter, the preparation of which is described above, is, as mentioned, adapted for orthochrom or pinachrome plates, and may also be used for the best commercial orthochromatic plates.

Which of the two methods, the one-plate or the three-plate, is the better, is difficult to say. Authorities like the brothers Lumière use the three different kinds of plates for obtaining their beautiful photograms in natural colours; whilst Dr Miethe obtains his very fine results on a single plate. With both methods, therefore, good results may be obtained.

Since recently considerable advances have been made in the manufacture of panchromatic plates, it is mostly advisable, at least for beginners, to use these plates for all three exposures, although they leave a good deal to be desired as regards red sensitiveness. Whenever short exposures are of great moment, and at the same time as perfect results as possible are to be obtained, then most decidedly the use of bathed plates is advisable.

Dr König uses for his three-color exposures an ordinary non-orthochromatic plate for the blue filter; for the green and red filters a pinachrome-bathed plate, which far exceeds in green and red sensitiveness the erythrosine and commercial panchromatic plates.

For the red filter exposure, under certain conditions, a pinacyanol-bathed plate is preferable (see below).

When one has decided to work with only one kind of plate, should all three exposures be made on one long plate, or should three separate plates, of the same kind, be used? The former plan presents a certain convenience for the expert; but so long as one is not absolutely certain of his

factors, it will often be necessary to develop one or other of the individual exposures somewhat longer, or harder, or possibly softer. Such individual treatment of each exposure is obviously impossible when all three exposures are made on one plate.

## Sensitisers

As already mentioned, commercial plates which are sensitised by adding ethyl red or pinachrome to the emulsion do not possess the same sensitiveness as bathed plates. An explanation of this fact cannot up to the present be given. Speaking from experience, bathed plates are three or four times as sensitive to red as those in which the emulsion is dyed, although the same emulsion may be used; curiously enough, the difference in the green is not so great. Whoever wishes, therefore, to take portraits or landscapes is advised to sensitise the plates himself.

For the preparation of panchromatic bathed plates, specially sensitive to red and green, ethyl red, orthochrom, and pinachrome are so far superior to the older sensitisers azaline, cyanine, isochinoline red, etc., that the latter are to-day no longer of any value. Ethyl red, orthochrom, and pinachrome belong to the class of dyes known as isocyanines. Ethyl red has the reddest shade and pinachrome the bluest. All three dyes give approximately the same sensitiveness for green; for red, pinachrome is by far the best and ethyl red the worst sensitiser.

So far pinachrome has not been surpassed by any dye of the isocyanine series, and actually satisfies almost all requirements of three-color photography as regards sensitising. Yet even with pinachrome it may occasionally happen that a satisfactory rendering of deep red tints may not be obtained. In such cases, the use of pinacyanol is indicated, which combines with the good photographic properties of pinachrome a power of sensitising very far into the red. Pinacyanol, when used like pinachrome, gives absolutely clean-working plates of extraordinary red sensitiveness which keep a long time. For preparing panchromatic plates, however, pinacyanol is not suitable, because the sensitising power for green is almost entirely absent. Mixtures with other dyes also have given no

good results. Even if pinacyanol is not actually an isocyanine, it shares with these dyes the good property of not markedly altering the gradation of the plates.

The method of using all the isocyanines is the same. Strangely enough, however, all commercial dry plates will not give equally good and clean-working plates when sensitised with these dyes. Many otherwise absolutely clean-working and admittedly excellent plates give always intense fog when sensitised with the isocyanines. Good results so far have been obtained with Seed, Lumière, Mawson's Celeritas, Paget Prize, Wratten & Wainwright, Gem Universal, and Marion's "Speed" plates. It must not be inferred that other plates will not give good results, but the above can be vouched for from experience.

The sensitising of the plates is effected in the following manner:—

| | | |
|---|---|---|
| Pinachrome . . . . . | $15\frac{1}{2}$ grains, | 1 g. |
| Alcohol . . . . . . | $3\frac{1}{2}$ ozs., | 100 c.cs. |

Dissolve by the aid of a gentle heat, and add—

| | | |
|---|---|---|
| Alcohol . . . . . | 21 ozs., | 600 c.cs. |
| Distilled water to . . . | 35 ,, | 1000 ,, |

Instead of this the commercial 1 : 1000 pinachrome solution may be used. The solutions of these dyes must be kept in the dark, and will then keep indefinitely.

The sensitising bath consists of—

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|---|---|---|
| Pinachrome solution (1 : 1000 as above) . . . . | 50–68 m., | 3–4 c.cs. |
| Distilled water . . . . . | 7 ozs., | 200 ,, |

In this solution the plates should be bathed, with continual rocking, and in absolute darkness, for three or four minutes, then washed for two or three minutes in running water, or in repeated changes of water.

If ammonia is added to the dye bath, the plates are not markedly more sensitive, and they will not keep for so long. In the above given quantity of bath not more than 700 square inches of plate area must be sensitised.

It is very important that the plates should be dried as quickly as possible. This is best effected, when a very large number of plates have to be dried, by a strong draught, which

may be caused by the suction of a stream of water or by a small electrically driven fan. The air should be first sucked through a tube filled with anhydrous calcium chloride to dry it, and then through a longer tube filled with cotton-wool to free it from dust. The plates should be placed in a metal box or cupboard which will shut close, and which should be provided, on the opposite side to where the air enters, with a hole for the escape of the air. In such a cupboard the plates may be dried with a good current of air in from fifteen to thirty minutes, and they will then keep for at least five or six months.

For those to whom the fitting up of such a drying arrangement is impossible, it will be quite sufficient to dry the plates in a metal box, without a current of air, by placing in the same, according to size, one or more dishes of anhydrous calcium chloride. The box should be made of metal or lined with metal, as in a wooden box the drying is much slower, on account of the porous sides. The drying in this metal box may be considerably hastened if above the plates is placed, in a suitably safe manner, a dish with calcium chloride. It is a well-known fact that damp air is lighter than dry and therefore rises, and will be therefore dried much quicker by the calcium chloride at the top of the box than when the latter is at the bottom. In winter time the box may be placed in a warm room.

A most excellent method of sensitising has been privately communicated by Freiherr von Hübl to Dr König. Dilute alcohol is used for bathing the plates. The advantages of this method are that the plates sensitised in the dilute alcohol dry much quicker, and are generally much cleaner, than those bathed in aqueous solutions; the washing is done away with; and further, in very hot weather the dilute alcohol does not soften the gelatine film of the plates so much as water. The sensitising bath consists of—

| | | |
|---|---|---|
| Distilled water . . . . | 7 ozs., | 200 c.cs. |
| Alcohol . . . . . | $3\frac{1}{2}$ „ | 100 „ |
| Orthochrom or pinachrome sol. (1:1000) . . | 68–100 m., | 4–6 „ |

or

| | | |
|---|---|---|
| Pinacyanol solution (1:1000) | 50–68 m., | 3–4 c.cs. |

The plates should be bathed for three to four minutes, not

washed, and be placed after well draining direct into the drying box.

It is not necessary to use pure alcohol: methylated alcohol is quite good enough.[1]

Contrary to the aqueous dye baths, these dilute alcohol baths will keep some weeks—naturally, in the dark—unchanged. This is of special importance if the plates are not sensitised in dishes, but a greater number are sensitised at once in upright grooved tanks, which require a tolerably large quantity of sensitising solution, so that the dye therein is not so soon used up.

It is well known that most photo-mechanical firms do not use gelatine dry plates for their orthochromatic or three-color work, but collodion emulsion plates, which are always coated shortly before use. The collodion emulsion is sensitised with suitable sensitisers, and these home-coated plates are very cheap. Unfortunately, the sensitiveness is extraordinarily less than that of gelatine dry plates. Notwithstanding this, the use of collodion plates for reproduction work, interiors, still life, and so on, is certainly advisable. Collodion emulsion plates, besides being very cheap, work very cleanly, are fixed in a few seconds, require but little washing, and are dried equally quickly. Collodio-bromide emulsion may be obtained commercially, as well as the sensitising solutions, so that we need not give further details.

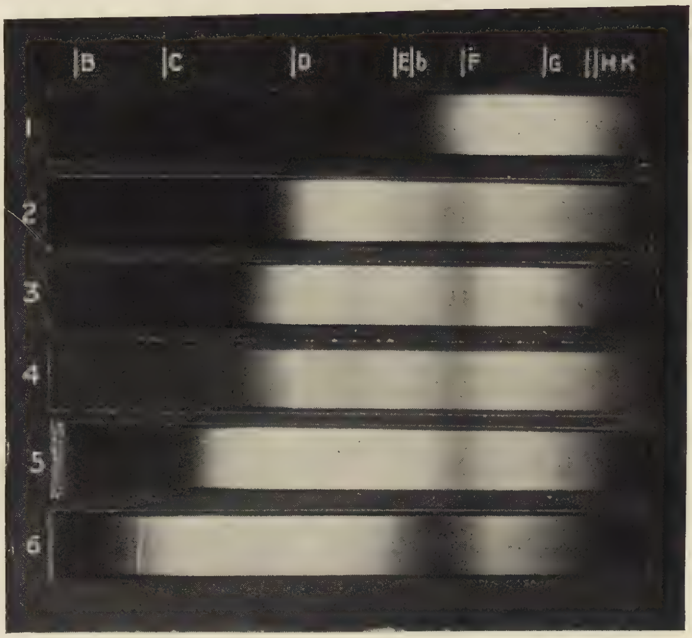
As sensitisers for the green filter plates, eosine, dibromo- and monobromo-fluorescine are suitable sensitisers; and for the red filter plates, ethyl cyanine, pinacyanol, and dicyanine.

In order to show the sensitising action of the various dyes, the following spectra, taken by Dr König, are given. They are all taken in a diffraction-grating spectrograph, with a Nernst lamp as the source of light, and the various lines are included in order to determine the colors.

1. Ordinary plate with the violet potassium line.
2. An erythrosine-bathed plate, showing the well-known yellow sodium or D line.
3. An ethyl-red bathed plate, showing the D line and violet potassium line.

[1] In England the old methylated spirit, and not the new mineralised rubbish, must naturally be used.—E. J. W.

Red. Orange. Yellow. Green. Blue. Violet.




SPECTRUM TESTS, TO SHOW ACTION OF VARIOUS DYES.

1. Ordinary plate. 2. Erythrosine-bathed plate. 3. Ethyl-red bathed plate.
4. Orthochrom-bathed plate. 5. Pinachrome-bathed plate.
6. Pinacyanol-bathed plate.

4. An orthochrom-bathed plate, showing the D, the green thallium and the potassium lines.

5. A pinachrome-bathed plate, showing the D and potassium lines.

6. A pinacyanol-bathed plate, showing the red lithium line between B and C, the D and the potassium lines.

### Exposure and Development

If the filters are ready and the plates have been prepared, the next point is the estimation of the ratio of exposures through the three filters. The best test subject is a clean white plaster bust, a color chart with as far as possible saturated red, yellow, green, and blue colors, and finally a scale of greys, which makes a decision as to the gradation of the negatives extremely easy. As a neutral grey is only a degraded white, it reflects all rays equally, and the reproduction of deep grey tones depends only on the gradation of the plates used, not in the least on the filters or the sensitising. A convenient grey scale is made by exposing a strip of matt bromide or platinotype paper in successive strips under a piece of opaque card, giving increasing exposures to each one so as to obtain an increasing scale of greys. Equally as good as the grey scale is a white cloth or paper crumpled up into a ball.

For the sake of simplicity we will assume that a pinachrome-bathed plate is exposed behind all three filters.

In order to be able to accurately determine the ratio of exposures, a day should be chosen with as constant a light as possible—that is to say, one with a blue sky, when the brightness and composition of the daylight will not change from exposure to exposure. The image should be focussed on the ground glass through the red filter, which is optically the brightest. The lens should be then well stopped down in order that the relative times of exposure may be determined with the greatest accuracy.

Behind our blue filter, we must expose four or five times longer than we should do were a filter not used, other conditions being absolutely equal; behind the green filter, the exposure with bathed plates will be three to four times longer than behind the blue filter; and behind the red filter the

exposure will be somewhat shorter than behind the green. In the case of panchromatic plates sensitised in the emulsion, somewhat longer exposures are required, especially behind the red filter. The three plates must be developed for the same length of time, and the resultant negatives must reproduce alike the plaster bust and the grey scale as far as possible. The high lights should be of equal density and the shadows show the same amount of detail; the steps of the grey scale should show the same gradation.

For determining the ratio of exposures the plaster bust and the grey scale are alone the standard. Anyone who has had any experience at all in ordinary monochrome photography will at once recognise which negative is rather over or under exposed, and will then with a second trial soon hit the correct times of exposure. If the rapid light-filters, which have already been mentioned, are used, then the ratio of exposures for the blue, green, and red is 1 : 2 : 2. Since the blue filter prolongs the exposure about four times, the total time of exposure for these filters is only twenty, if the time for an ordinary exposure without a filter is taken as one. There are commercial filters with which the ratio of exposures is perhaps given as 1 : 1 : 3; yet according to the author's experience, frequently the blue requires an inordinately long exposure, which amounts to about fifteen to twenty times that without a filter. If we reckon according to this the total time for a three-color exposure, we obtain $15 \times (1+1+3) = 75$. It will be seen from this that the mere statement of the ratio of exposures gives no standard of the performance of a set of filters, and that such statements are only fitted to lead the purchaser into error.

The ratio of exposures found should be accurately noted. With cloudy, dull weather, when the red and green rays predominate, one may often meet with disappointments, and one should therefore always choose bright days with normal light for the first exposures. We shall see later, when talking of the chromoscope, how one may test in a very simple manner the daylight which exists at any particular time.

The image of the color chart photographed simultaneously with the plaster bust and grey scale shows whether the filters are acting properly. In the negative taken through the blue filter, violet and ultramarine should appear very

dense, and blueish red moderately so. Green, yellow, orange, and yellowish red should not have acted at all. In the negative taken through the green filter, emerald green should be very dense, chrome yellow and yellowish green less so, ultramarine and orange still less, whilst red should be clear glass. The negative exposed behind the red filter should show yellow and orange very dense, red somewhat weaker, and green very thin, whilst ultramarine should be clear glass. White should obviously on all three negatives be equally dense, and black be clear glass.

If the negatives do not answer to these requirements, the filters are not correct. In most cases a failure will be seen with the green filter exposure if the filter is not prepared with sufficient care. If the blue is too dense and the green and yellow somewhat too thin, the filter must be made more yellow or somewhat darker; if the blue is too thin, the filter contains too much yellow, or it is too dark. In the one as in the other case the remedy is obvious. Theoretically a dark blueish red should be very dense in the blue filter negative, so that later in the colored picture it shall not appear too yellow. As a matter of fact, however, it is impossible to obtain this result with blue filter negatives. Even if one could expose long enough, with a suitable filter, to bring this red to its correct action, the yellow, which should be cut out, would always act too strongly, because all yellows occurring in nature contain a lot of red (and green).

As regards the developer, any good clean-working developer may be used; but hard working kinds, the most noted of which is hydroquinone, should be avoided. Specially good results are obtainable with a paramidophenol developer of the following composition:—

| | | | |
|---|---|---|---|
| 1. | Paramidophenol hydrochloride . | 15 grs., | 15 g. |
| | Anhydrous sodium sulphite . | 45 „ | 45 g. |
| | Distilled water . . . | 1 oz., | 500 c.cs. |
| 2. | Potassium carbonate . . . | 70 grs., | 70 g. |
| | Distilled water . . . . | 1 oz., | 500 c.cs. |

Instead of the anhydrous sulphite, double the quantity of the sodium sulphite, crystal, may be used in No. 1.

The paramidophenol should be first dissolved in a little water and then the solution of the sulphite added; the

paramidophenol base will separate out in a crystalline form, so that No. 1 solution must always be well shaken before use. Just before use mix 1 part of No. 1, 1 part of No. 2, and 5 parts of water. The duration of development should be from $2\frac{1}{2}$ to $3\frac{1}{2}$ minutes.

The red-sensitive pinachrome plates, which should have been carefully protected, during the preparation and placing in the dark slides, against the red light, must be laid in the developer in an absolutely dark place, far removed from any source of red light. Only after a minute ought the developing dish to be brought carefully nearer to the red light, without taking the plate out of the dish; otherwise absolute fogging will be the immediate result. As in color photography an accurate observance of correct exposures is more important than in ordinary monochrome photography, watching the progress of development is of far less importance: anyone will soon find out how long his plates must be developed with his chosen developer. Continued forcing of the plates, in order, in cases of under-exposure, to drag as much as possible out of them, is in color photography a total mistake: it is much better to repeat the exposure.

The character of the negatives must vary according to the nature of the printing process which is to be used later on: thus the process of superimposed carbon tissues requires extremely delicate negatives, pinatype more vigorous ones. In no case, however, should the negatives be hard or show excessive density in the high lights.

It is not advisable to start first with portraits or landscapes, but flower or still-life studies should be first tackled, in which, together with the bright colors, some white is present. The lighting of the objects to be taken should be soft. Brilliant reflecting lights, which easily cause false color tones, should be avoided. When these are successfully rendered, then one may turn their attention to portraits and landscapes. In landscape work, especially when brilliantly lit, the rendering of the greens is often very difficult. According to the authors' experience and that of others, it is often advantageous to use an additive filter for the green, instead of the subtractive one described above. This filter, the preparation of which is described on p. 85, requires, it is true, a somewhat longer exposure, but it gives a denser negative in the greens. The

fault which the use of the additive instead of the subtractive filter introduces, is that pure blue is rendered a little too red, but this is of little moment in landscape work.

In all three-color work, it must not be forgotten that our eyes are very much more sensitive to delicate shades of color than to slight differences in luminosities of colors. It is a recognised fact that photography always reproduces shadows much too dark; but we have accustomed our eyes to this, and we do not find fault with a print because perhaps an object therein may appear a little too dark or too bright. In color photography, however, it is quite different. Moderately dark and bright colors are always well reproduced; light, delicate compound colors, such as the tints of the face or a light grey, present, however, great difficulties, because with such colors a slight predominance even of one of the fundamental colors offends very strongly. Time of exposure and degree of printing must be accurately adjusted, if the results are to be satisfactory; otherwise it may happen that a pure light grey may appear reddish, or the tint of the face in portraits may possibly be greenish. These are difficulties which can only be overcome by experience.

The constituent negatives may naturally, like all other negatives, be reduced or intensified. Sometimes the high lights will be too dense, whilst the rest of the negative is exactly right; then the negative is too hard, and reduction with ammonium persulphate should be used, for, as is well known, this first attacks the densest portions of the negative. If the whole negative is too thin, but shows all details, then one may proceed to intensify. Thus it is often possible, if too gross errors in exposure have not been made, to bring the three negatives into order. Naturally, it is much better always if the negatives can be used without subsequent treatment.

In order not to unduly enlarge the scope of this work, no formulæ for the current operations, such as reducing, intensifying, etc., have been included, for they can be found in any text-book on photography. (*The Figures, Facts, and Formulæ of Photography*, price one shilling, gives them all, in convenient form.—Eds.)

Retouching of the negatives should be solely confined to careful correction of spots and defects in the plate. Actual

retouching in the ordinary sense should, at any rate in the beginning, be carefully avoided, for it is extremely difficult to estimate the result of this, and then only after long experience.

Very great care must be taken as to the dark-room illumination. The commercial red glass is by no means always safe, and when it is, it is so dark that one might almost as well use a piece of slate instead of it. The best way is to make a red screen for oneself as follows, for this transmits no yellow, green, or orange, and is perfectly safe. A sheet of glass should be coated, as described under "Filters," p. 32, with the following solution:—

| | | |
|---|---|---|
| Gelatine . . . . . | 93 grs., | 6 gs. |
| Water . . . . . . | $3\frac{1}{2}$ ozs., | 100 c.cs. |
| Tartrazine, pure . . . . | $12\frac{1}{2}$ grs., | 0·8 g. |

To every 16 square inches of glass should be allowed from 135 to 169 minims of the dyed gelatine. A second sheet of glass should be coated with crystal violet according to the following formula:—

| | | |
|---|---|---|
| Crystal violet . . . . | 31 grs., | 2 g. |
| Glacial acetic acid . . | 5–6 drops, | 5–6 drops. |
| Water . . . . . | 14 drachms, | 50 c.cs. |

To 100 parts of a 6 per cent. solution of gelatine should be added 7 to 8 parts of this dye solution, and 135 minims of the dyed gelatine coated on 16 square inches of glass.

When dry, the two sheets of glass should be placed with their films in contact, and then bound round the edges with paper or cloth. This compound red screen is used in the dark-room lantern, and only transmits the extreme red end of the spectrum, to which panchromatic plates are comparatively little sensitive. One must, however, be very careful even with this light, and never bring the plates into close proximity to the same; and even at greater distances one should avoid exposing the plates—for longer, at all events, than two seconds. The interior of the lantern should be roomy, so that this glass screen is not heated too strongly; otherwise both dye and gelatine will be destroyed. If the grooves in the front of the lantern will permit, it is frequently advisable to separate the glasses by narrow strips

of card at the bottom and the two sides, and leave the top unbound, so that any moisture driven out of the gelatine may escape. Similar light-filters for dark-room lanterns, composed of dyed gelatine, may be obtained commercially. For those who have the electric light, very convenient lamps may be obtained in which the globe is contained in an outer cylinder which can be filled with solutions of dyes. These have been used with great satisfaction for a long time by Dr König. In England, also, the tank dark-room lamps, which are constructed with a glass tank which can be filled with dye solutions, will also be found very satisfactory.

In order to avoid any undesirable confusion afterwards, it is best to mark the negatives, and call that taken behind the blue filter *yellow*, that taken through the green filter *red*, and that through the red filter *blue*. The safest plan is to write these words with a pencil in one corner of the plate before exposure. The pencilled word can be easily read on the finished negative.

### Printing the Constituent Negatives

Three monochrome prints must now be made from the three negatives, and in a suitable manner brought into register. Almost every printing process which has been used is based on the light-sensitiveness of the bichromates in the presence of organic matter, and, according to the nature of the organic substance, the methods are called carbon printing, gum-bichromate, pinatype, dusting-on process, etc. Quite an original printing process, however, is pinachromy, a description of which will be given later.

Very beautiful results are unquestionably given by the process worked out by the brothers Lumière, the accurate details of which they have published. Unfortunately, this method is extremely subtle, and requires so much skill and perseverance that the average amateur, and still more the professional photographer, who cannot spare the necessary time, will be hopeless about it.

Lumière's method can only be briefly described here: whoever is interested in its details can obtain a pamphlet from the inventors.

Bichromated gelatine is coated on paper, which is pre-

viously made non-expansive by a preliminary coating of collodion and spirit varnish. This is extremely important, for when using ordinary paper as a support for the bichromated gelatine the constituent images can never be obtained so that they will accurately register, as the paper, under the action of the chromated gelatine film, is very much distorted. On this non-expansible bichromated gelatine paper the three negatives are printed, the films transferred to glass, and developed with warm water, exactly as in the carbon process. The gelatine reliefs thus obtained are dyed with suitable dyes. So far it is quite easy. Now, however, the images adhering to the glass plates must be transferred one after the other to the same support. Here it may too easily happen that one picture will not, perhaps, separate from its glass, or the other two will adhere too firmly to their temporary support; and there are other disasters. The constituent images are coated with gelatine, and can be transferred to glass as well as paper. The latter is indeed specially difficult, for which reason as a rule transparencies only are made by this process.

Sanger-Shepherd's printing process is comparatively simple, and briefly is as follows:—From the blue negative taken through the red filter an ordinary black silver transparency is made on a lantern plate, and this converted in the well-known way into a Berlin blue. On this blue transparency the other two constituent images are cemented. To make the latter, gelatine containing silver bromide is coated on thin celluloid, sensitised with bichromate, and dried. They are then printed under the red and yellow negatives with the celluloid next to the film of the negative, then developed with warm water, the silver bromide removed from the films by fixation with hypo, and the colorless gelatine reliefs thus obtained stained with suitable dyes. By the dodge of exposing the films through the celluloid the troublesome transfer of the constituent images is obviated. This process is suitable only for transparency-making.

Dr König has worked out a somewhat similar process, using to some extent Lumière's formulæ. First, as regards the blue image, this may be obtained on celluloid, exactly like the other two images ; or a silver image may be converted into Berlin blue, as follows :—The transparency, which should

be clear and soft, thoroughly fixed and well washed for at least half an hour, should be immersed in the following solution :—

| | | |
|---|---|---|
| Ammonium ferric oxalate . . | 8 grs., | 0·5 g. |
| Potassium ferricyanide . . . | 8 „ | 0·5 g. |
| Glacial acetic acid . . . | 84 m., | 5 c.cs. |
| Water . . . . . | $3\frac{1}{2}$ ozs., | 100 „ |

In this solution the image quickly assumes a blue tone; it should then be washed for a short time, and the silver compounds removed by immersion in an ordinary acid fixing bath, and the plate again well washed. As by even the very faintly alkaline tap-water the tone of the image becomes more reddish, the transparency should be immersed, after washing, for one or two minutes in a 1 or 2 per cent. solution of hydrochloric acid. The color is converted by this into a brilliant greenish blue. The plate should now be washed in repeated changes of distilled water, and dried.

To make the constituent images by means of bichromated gelatine, the following is the process:—Old, useless roll-films should be sensitised by immersion for five minutes in a 3–4 per cent. solution of potassium or ammonium bichromate, and dried in the dark. It is practically immaterial which of the two salts be used. All films, however, are not suitable for this purpose, as many commercial films are so hardened that they will not dissolve in warm water. This should be tested for before sensitising the films, by seeing whether the gelatine is easily and completely soluble, and water at from 95 to 105° Fahr. should be used. Films may be obtained commercially especially prepared for this method. Such films may, however, be prepared at home without much trouble.

Old and useless films, of which the celluloid must be of good polish and not scratched, can be freed from their gelatine film by immersion in lukewarm soda solution and gentle friction. They must then be well washed in clean water and the films whilst wet squeegeed on to an accurately levelled plate-glass slab, so that they may be coated with the following mixture: carpenter's fine glue, 309 grains (20 g.) should be soaked in water for twelve hours; gelatine, 309 grains (20 g.) should be soaked in water for one hour, then the water poured off and the swollen glue and gelatine weighed, and enough water added to make the total weight $9\frac{1}{2}$ ozs. avoir.

(270 g.). A gentle heat should then be applied till perfect solution is obtained; then should be added 4½ grains (0·3 g.) of fast red D (echtrot D) and 616 minims (35 c.cs.) of alcohol, and the mixture filtered through a felt filter-bag which has been previously damped with hot water. Just before use 25 parts of a 13½ per cent. solution of ammonium bichromate should be added to 100 parts of the above gelatine-glue solution.

Of this bichromated mixture 120–135 minims (7–8 c.cs.) should be coated, by lamplight, on every 16 square inches (100 qcm.) of the celluloid, and distributed by a glass rod bent to an L shape before it sets. When it has set firmly, the films should be lifted up and fastened by the corners to a flat board by pins, and dried in the dark. The same precautions must be taken as in drying ordinary carbon tissue—that is to say, they must be dried quickly, in pure air, and at not too high a temperature. In damp, cold weather it is therefore advisable to dry them in a chloride of calcium box. The films must be dry in twelve hours.

The purpose of the red dye is to enable the image to be seen during development, and it should, moreover, according to Lumière, prevent the formation of too high a relief, as the red gelatine prevents the too great penetration of the actinic rays into the film. Obviously, the orange-colored bichromate by itself acts in the same way, so that the addition of the fast red dye has only the first effect.

Bichromated gelatine films, thus prepared, will only keep for a day or two; their keeping properties are, however, increased if to the above-given quantity of gelatine-glue mixture 31 grains (2 g.) of acid citrate of potash be added.

One can naturally also coat films with gelatine without the bichromate, and then they will keep indefinitely, but require sensitising before use.

The use of the red dye with these films is impossible, as the best part of it dissolves in the bichromate bath. Some gelatino-bromide of silver emulsion should therefore be added to the glue and gelatine, and it may easily be prepared as follows:—

| | | | |
|---|---|---|---|
| 1. | Gelatine . . . . . | 154 grs., | 10 g. |
| | Water . . . . . | 3½ ozs., | 100 c.cs. |
| | Potassium bromide . . . | 62 grs., | 4 g. |

Allow to soak for a short time, and then melt in a water-bath at 120° Fahr.

| | | | |
|---|---|---|---|
| 2. | Silver nitrate . . . . | 77 grs., | 5 g. |
| | Distilled water . . . | 14 drms., | 50 c.cs. |

Dissolve and add, by lamplight, in small portions to No. 1, shaking well and vigorously between each addition.

The yellowish-white emulsion thus obtained should be digested for a quarter of an hour at about 120° Fahr., with constant shaking, and then poured out into a flat dish to set. After standing for five or six hours in a cool place, the emulsion will have set to a firm jelly. This should be cut up into narrow strips with a horn knife, or scored through with a silver table fork, and then washed for about four to five hours in cold water, which must be frequently renewed or running. The shreds should then be collected on a piece of clean linen, excess of water squeezed out with light pressure, and then melted in a beaker with 2 ozs. 5 drachms (75 c.cs.) of alcohol.

For coating the films the mixture of glue, gelatine, and alcohol should be used, without the red dye, and to the above-stated quantity (9½ ozs. or 270 g.) should be added 14 drachms (50 c.cs.) of the bromide of silver emulsion. The silver bromide only gives softer prints ; it acts to some extent as a pigment ; and its sensitiveness to light in this particular instance is not employed. In spite of this, however, the gelatine mixture or the dried films should not be unduly exposed to daylight, or they will become too dark. These films are, before use, sensitised in bichromate exactly like the commercial roll-films, and they have the advantages of being cheaper and of the film always being soluble. When the films are dry the celluloid should be cleaned with a damp rag from any adhering bichromate, which would naturally produce light spots in the picture. Any contamination of the gelatine side by dust and so on is immaterial, as the top gelatine film dissolves during development.

The film is now placed in the printing-frame with the celluloid in contact with the film of the negative. The printing-frames must have strong springs, so that good contact be made between the film and plate, which may be obtained by backing up the films with card, etc. The light should fall as far as possible at right angles on to the frame during printing,

so that the celluloid film between the negative and sensitive gelatine should cause as little fuzziness as possible. Many place round the printing-frames cardboard funnels, so that only the direct rays can reach the plate. This method is specially advisable when using thick celluloid films.

So that later the colorless prints may be distinguished, that which is to be stained yellow is left with all four corners on, that which is to be stained red has one corner cut off, and two corners are cut off that which is to be stained blue—that is, assuming that these prints will not be used as transparencies, as described above. We again repeat: the negative taken through the blue filter gives the yellow image; the negative taken through the green filter gives the red image; the negative taken through the red filter gives the blue image.

The bichromated gelatine is very sensitive to light, and with clean negatives and bright, diffused daylight an exposure of from two to four minutes is generally enough. As the image during exposure is visible, the progress of the action of light can be followed, and the correct time of insolation will soon be learnt without the aid of an actinometer.

After printing, the films should be developed in warm water at 95–105° Fahr., and the image will appear either with a white or pale rose color, according to the printing material used.

The prints must show all details distinctly; if the shadows only are reproduced, the exposure has been too short; if the high lights are covered and development proceeds very slowly and with difficulty, the print was exposed too long. Care must be taken in the latter case not to force the development with hot water; the celluloid will not stand high temperatures, and cockles without fail.

The red color of the image disappears with longer washing completely; the uncolored gelatine image should be rinsed with clean water and then dried, fastening it by the corners to a board. When using the silver bromide films, the silver salt must be next removed after development by fixation, and the now glass clear image well washed. If the silver bromide has become distinctly grey, the reduced silver remains undissolved, and would degrade the picture. Then some potassium ferricyanide should be added to the fixing

bath; but naturally an acid fixing bath must not be used, but merely a pure solution of ordinary hypo.

The well-washed prints should be dried as described above.

For staining the individual images we adhere to Lumière's formulæ, which we have found to be the best; only the chrysophenine should be used for convenience' sake in the form of its chemically pure ammonium salt, since the commercial chrysophenine is too impure and too insoluble.

### I. Dyeing the Yellow Picture

*The yellow dye bath.*

| | | |
|---|---|---|
| Chrysophenine-ammonia salt (aurophenine) . . . . | 31 grs., | 2 g. |

Dissolve in a little hot water and add—

| | | |
|---|---|---|
| Distilled water to . . . | 35 ozs., | 1000 c.cs. |

and add—

| | | |
|---|---|---|
| Alcohol . . . . . | 7 „ | 200 „ |

As chrysophenine forms a calcium salt which is very insoluble, and most ordinary tap water contains, as is well known, more or less lime salts, the use of this should be avoided in preparing the yellow picture. If the yellow picture is not from the start developed with distilled or rain water, it must after development, or after fixation and washing, be immersed for about five minutes in very dilute (about 1 per cent.) solution of hydrochloric acid, and then washed in frequent changes of rain or distilled water.

If the dyed yellow print when looked through is not absolutely golden yellow and clear, but brownish and cloudy, it is a sign that the gelatine film contained calcium salts.

The image, freed from chalk by the hydrochloric acid, then well washed and dried, should be immersed in the above bath and frequently rocked. The dyeing process proceeds very quickly, in about fifteen to thirty minutes. The image should be rinsed, when it appears sufficiently stained, with distilled water, and then dried.

### II. Dyeing the Red Picture

*The red dye bath.*

| | | |
|---|---|---|
| Pure erythrosine (3 per cent. solution) . . . . | 84 minims, | 5 c.cs. |
| Water . . . . . | $3\frac{1}{2}$ ozs., | 100 „ |

The dry print should be placed in the dye bath. The dyeing takes from one to five hours. The image, when sufficiently stained, should be rinsed, and then, in order to make it more stable to light, should be immersed for two minutes in a 5 per cent. solution of cupric sulphate, again rinsed with water, and dried.

### III. Dyeing the Blue Picture

*The blue dye bath.*

| | | |
|---|---|---|
| Pure diamine blue FF (3 per cent. solution) | 118 minims, | 7 c.cs. |
| Fine glue (15 per cent. solution) | 118 „ | 7 „ |
| Water | $3\frac{1}{2}$ ozs., | 100 „ |

The dyeing is effected precisely in the same way as for the other pictures. The glue in this dye bath produces a slower and more even dyeing of the picture. The dyeing process proceeds somewhat slowly, taking from two to ten hours. After dyeing, the blue image is treated exactly like the red with cupric sulphate, in order to make it more stable to light. The yellow image does not need this treatment with the copper, as chrysophenine is in itself sufficiently stable to light.

It is not advisable to try and hasten the dyeing of pictures by using more concentrated dye baths, as the brilliancy of the colors suffers considerably.

### Superposition of the Three Constituent Images

The three constituent prints should be first temporarily laid one on top of the other, in order to estimate the effect. Then, according to whichever color predominates, one or other of the pictures can be intensified by renewed immersion in the dye bath, or reduced by soaking in clean water, both obviously only to a certain extent. The gelatine will take up, even by much longer treatment with the dye solutions, only a definite maximum amount of dye; on the other hand, by too strong reduction of the pictures, the half-tones are easily lost.

The blue picture can only be reduced when to the water a few drops of a solution of glue are added.

By careful retouching, the final effect of the picture can be frequently improved, as by touching up those parts of the negatives which print too strongly.

The pictures, when treated with cupric sulphate, cannot be reduced; it is advisable, therefore, only to treat the red and blue images to this bath when they are quite satisfactory.

If the three prints together give a harmonious picture, the blue image should be fastened by one corner to a sheet of glass—that is, if the blue picture is not prepared direct on glass. When dry, the yellow picture is laid on top so that the outlines coincide, and fastened down with a little paste, gummed paper, or rubber plaster; and the green picture thus obtained is allowed to dry under pressure of a clip; and finally the red image is fastened down in the same way. For protection, a cover-glass is finally laid on top, and the finished picture bound round the edges with paper or calico binding-strips.

The fitting of the separate pictures together is very easy, assuming that the negatives accurately correspond with one another: the films should not be too thin, otherwise they will be very liable to cockle.

The colored transparencies are very stable to light, so that they may be exposed for several months to diffused daylight without any marked fading.

Pinatype may also be used for making three-color transparencies. The pictures are much more perfect and sharper than those obtained by the above method. A description of this process will be given later.

Freiherr von Hübl recommends the following baths for dyeing the three constituent images:—

*Red dye bath.*

| | | |
|---|---|---|
| Erythrosine (1:200) . . . | 84 minims, | 5 c.cs. |
| Alcohol . . . . . | 168 „ | 10 „ |
| Water . . . . . | $3\frac{1}{2}$ ozs., | 100 „ |

*Blue dye bath.*

| | | |
|---|---|---|
| Blueish fast green (Bayer) (1:200) | 336 minims, | 20 c.cs. |
| Alcohol. . . . . . | 168 „ | 10 „ |
| Glacial acetic acid . . . | 10 drops, | 10 drops. |
| Water . . . . . . | $3\frac{1}{2}$ ozs., | 100 c.cs. |

*Yellow dye bath.*

| | | |
|---|---|---|
| Naphthol yellow SL (1:200) . | 168 minims, | 10 ccs. |
| Alcohol . . . . . . | 168 „ | 10 „ |
| Glacial acetic acid . . . | 10 drops, | 10 drops. |
| Chrome alum (sat. solution) . . | 84 minims, | 5 ccs. |
| Water . . . . . . . | 3½ ozs., | 100 „ |

MM. Lumière recommend the following:—

*Red dye bath.*

| | | |
|---|---|---|
| Erythrosine J (3:100) . . . | 42 minims, | 2·5 ccs. |
| Water . . . . . . . | 3½ ozs., | 100 „ |

*Blue dye bath.*

| | | |
|---|---|---|
| Pure diamine blue F (3:100) . | 84 minims, | 5 ccs. |
| Water . . . . . . . | 3½ ozs., | 100 |
| Hard glue (15 per cent. solution) . | 118 minims, | 7 „ |

*Yellow dye bath.*

| | | |
|---|---|---|
| Chrysophenine G . . . . . | 6·2 grs., | ·4 g. |
| Water . . . . . . . | 3½ ozs., | 100 ccs. |

Dissolve at 160° Fahr. and add—

| | | |
|---|---|---|
| Alcohol . . . . . . | 84 minims, | 5 ccs. |

### Printing upon Paper

It is not possible to obtain prints on paper by the last-described and comparatively simple process. Although color transparencies and lantern slides may be ever so beautiful, yet the public at large want above all things pictures on paper, and these have hitherto been somewhat difficult to obtain.

To obtain pictures on paper, we must, if we exclude all photo-mechanical processes—as we shall do in this work—either use the extremely difficult and roundabout method by which MM. Lumière made their beautiful prints, or we must print the three constituent negatives on three different colored carbon tissues, and then transfer the three prints one on top of the other on the one support. The pigment tissues suitable for this process naturally contain insoluble and more or

less opaque earthy pigments. The result of this is that the final effect of a three-color print prepared with such pigments can never attain the brilliancy given by a print obtained with dyes. Only the transparent gelatine constituent parts of pictures can give the full effect: when the pictures are composed of the less transparent pigment prints, the upper films must hide more or less of those lying underneath. It is also naturally very difficult to transfer three pigment prints on to one support so that they shall absolutely coincide. One has to contend here also with the unequal expansion of the paper, which has been attempted to be overcome by cutting the three pieces of paper in one direction of the paper roll. Such a method for the preparation of three-color paper pictures was published by Hoffmann, but it has not been a success, because the results left much to be desired, for the above reasons. Full details of this process are given in *Die Praxis der Farbenphotographie*, by A. Hoffmann.

Recently the Rotary Photographic Company have introduced commercially special tissues for three-color work, which consist of thin celluloid films coated with colored gelatine, which have to be sensitised with bichromate and then exposed through the back. After developing with warm water, the first print is squeegeed on to paper and the specially prepared celluloid stripped off. The second print is superimposed on the first, the celluloid stripped off, and finally the third print superimposed on the other two.

The gum-bichromate process may also be used for making colored prints. It is well known that very frequently in monochrome gum printing several impressions are taken one on top of the other, in order to obtain a good result. For three-color work the process is just the same, and the three constituent negatives are printed one on top of the other with the correspondingly colored bichromated gum films, which are coated in succession on the same paper. This process is really only suitable for large-sized prints. A gum process specially suitable for three-color has been worked out by Perscheid of Leipzig, and it should give excellent results. Full details will be found in the small work by Perscheid on the subject.

Another process for the preparation of prints has been patented by Sanger-Shepherd and Bartlett. Three images

are obtained on celluloid films by the process as described on p. 50 ; these are stained with suitable dyes, and the damp colored film is brought into contact with paper coated with soft gelatine. The dye is transferred fairly quickly into the soft gelatine, and when the dyed film is lifted up the colored image is seen on the paper. The same process is gone through with the two other constituent images, which must, of course, be laid on the paper so that the outlines coincide. The dye is sucked out of the image by the gelatine, and the celluloid images, which thus become colorless, can again be dyed, and can be used for making prints. Like the dye solutions, they are quite permanent. The process of printing may be examined from time to time by lifting up one corner of the paper.

Another process introduced by the Lumière N.A. Co. is briefly as follows:—The three constituent negatives are obtained in the usual way, and that taken through the red filter is varnished with celluloid varnish. A sheet of glossy bromide paper is soaked in water for at least half an hour, then, whilst wet, squeegeed into contact with the red filter negative, and exposed, developed, and fixed. After thorough washing, the image is converted into Berlin blue. Prints from the other two negatives are now taken by printing bichromated gelatine films on thin celluloid, the celluloid being in contact with the film of the negative; then developed with warm water, and stained up in the red and yellow dye baths, and then successively transferred on to the blue image, the celluloid being stripped in each case.

The Pinatype process is distinguished from these processes in that it does not consist of three films cemented together. As will be seen from the description, a single thin film of gelatine carries all three colors, which thus combine in an extraordinary manner. It cannot be denied that the roundabout process of the transparencies and print-plates is inconvenient; but if a good print-plate has once been made, many prints may be made by means of the same in a very simple way. As transparencies must be used for printing, the often-desired opportunity for retouching is now offered. The preparation of enlarged pictures by pinatype is very easy.

Those who work the additive processes, as described in the

second part of this book, and use the chromoscope to show the prints, will heartily welcome pinatype. For excellent pinatypes may be prepared from the chromoscope transparencies: only pure blue tones will appear a little too raw—on account of the different property of the additive green filter. With equally happy results may the transparencies used for pinatype be tested for their correctness in the chromoscope.

### The Preparation of Transparencies by means of Pinatype

Transparencies may be prepared by pinatype even more easily than prints on paper, and they show extraordinary sharpness and transparency—greater than transparencies by any other process.

From the transparency from the negative taken through the green filter the red image is first produced on a print plate, fixed and dried.

The red image is laid on a levelled sheet of plate-glass and coated with the following mixture,[1] in the manner described on p. 30:—

| | | |
|---|---|---|
| Emulsion gelatine (best hard) | 77 grs., | 5 g. |
| Water . . . . . | $3\frac{1}{2}$ ozs., | 100 c.cs. |
| Ammonium bichromate . . | 31 grs., | 2 g. |

The gelatine should be cut up small and soaked in the water for about half an hour, and then dissolved by the aid of heat, then the bichromate powdered and added, and the mixture filtered through a felt filter. On every 16 square inches (100 qcm.) should be coated 67–84 minims (4–5 c.cs.) of this gelatine mixture. The preparation of the gelatine mixture and the coating of the plates can be performed by weak daylight or artificial light. When the gelatine has set, the plates should be dried in a moderately warm place, free from dust, in the dark. The films will keep for several weeks without change. The transparency from the negative taken through the red filter is now placed on the bichromated gelatine so that its outlines exactly correspond with the red image, which is easily done with the aid of a magnifying glass. The plate, which is kept from shifting by clips or in a

[1] The mixture may be used for the print-plates.

printing-frame, is exposed about two and a half times as long as was necessary for the red impression. This long exposure is necessary, because a part of the bichromate penetrates by diffusion into the gelatine of the red impression, so that the light-sensitiveness of the last film is reduced. An increase of the proportion of the bichromate is not advisable, and it has been proved that a separation of the two gelatine films by a coating of collodion or celluloid varnish or the like is inadvisable. After printing, the plate is well washed, immersed in weak bisulphite solution for about five minutes, in order to clear the whites, and again washed, and dyed blue.

In precisely the same way, on this red + blue image a film of bichromated gelatine may again be coated, and on this the yellow image produced; it is, however, simpler and safer to make the yellow image separately, and to use this as a cover-glass for the transparency. In this case the yellow image must be reversed to the blue + red.

The necessary reversed blue-filter transparency, which is used to make the yellow impression, may be made either by means of pinatype (1), or by the ordinary photographic method in the camera (2).

1. To use this process, a sensitised print-plate is exposed about as long under the blue-filter transparency as is necessary for a yellow printing plate, and then deeply stained in a solution of —

| | | |
|---|---|---|
| Pinatype black-brown . . | 31 grs., | 2 g. |
| Water . . . . . | 3½ ozs., | 100 c.cs. |

When stained, it should be washed for a short time and then dried. If the transparency is hardened in the fixing solution described above, the tone becomes blackish: this fixation is, however, not essential.

The gradations of light and shade are so produced in the colored films which are used to make the prints that they consist of hardened gelatine films evenly colored but of different thicknesses in different parts of the image, corresponding to the action of light. If now a damp gelatine paper is brought in contact with the surface of the image, which has everywhere the same amount of dye, the dye will be evenly given up to the paper. The dark parts of the picture will only slowly acquire vigor, in any case not proportional to

the thickness of the dyed film, so that it is impossible to obtain a harmonious result.

On a similar principle to that outlined above is founded the printing process discovered by Léon Didier, which has been further worked by the Hoechst Dye Works, and commercially introduced under the name of "Pinatype." As a detailed description of this process may be obtained through all dealers, only a few general statements will be made here.

If a gelatine film impregnated with bichromate be exposed to light under a negative, it is well known that on those places where the light acts the bichromate is reduced and the gelatine hardened. If now the undecomposed bichromate be removed by washing in cold water, a faintly visible image is obtained, which consists of hardened and unhardened gelatine. This image-bearing film behaves very differently to aqueous solutions of different dyes.

I. By the majority of dyes the whole film is completely or almost evenly stained; the staining can with some dyes be wholly or partially removed by washing with water; with others, however, it is not so.

II. A few dyes only stain the hardened gelatine more deeply than the unhardened, as they combine with the chromium oxide which is formed on the exposed parts (see Selle's process further on).

III. Finally, there are some dyes which only stain the unexposed gelatine; the hardened gelatine, however, they leave more or less free from stain. Between these three groups of dyes exist numerous intermediate groups, which may be sharply divided into classes according to their behaviour towards gelatine. The dyes of the last-named group are those which are used under the name of "Pinatype dyes" for the pinatype printing process.

These pinatype dyes must possess the following properties:—

1. They must be sufficiently soluble in cold water.

2. They should stain the unhardened gelatine very deeply, but not the completely hardened gelatine.

3. They ought not to be removed from the gelatine by washing.

4. They should quickly transfer to gelatined paper brought into contact with the dyed film.

5. The sharpness of the image must remain when the prints

dry, and this ought not to suffer by long soaking of the prints in water.

6. The dyes should be permanent in light.

All these qualities are combined in the pinatype blue, red, and yellow dyes which have been selected for three-color photography. The stability of the dyes to light is so great that after a year's exposure to the full sun the blue and red remain unchanged, and the yellow is only slightly darkened.

As the pinatype dyes, as mentioned above, possess the property of leaving the exposed gelatine unstained, but of staining the unexposed, it is obvious that a pinatype print is a true representation of the negative used; that which was on the negative clear appears also on the print clear, and *vice versa.* In order to obtain a positive, we must expose the bichromated gelatine film under a positive. As with all photographic processes, it is of great importance that the sensitive film should be correctly exposed. The print-plates (for thus are called the glass plates coated with gelatine) are sensitised by bathing in about a 2½ per cent. solution of bichromate, and require about the same exposure as a P.O.P. print. After washing out the undecomposed bichromate, the print-plate is laid in a solution of one of the pinatype dyes, and there is formed, assuming that the plate was correctly exposed, after a few minutes a vigorous positive rich in detail. When the image appears sufficiently stained, the excess of dye is removed by washing in water, and the plate brought into intimate contact with damp gelatined paper, exactly as in the above-described Sanger-Shepherd process.

Here there is, however, formed very quickly a very vigorous print, sharp as a hair, which reproduces all the gradations of the original negative or positive. This is the fundamental difference between Sanger-Shepherd's process (see p. 59) and pinatype: in pinatype the image is formed of gelatine of various degrees of hardness, the print-plate is on the surface, and, corresponding to the action of light, is variously stained; as the gelatine which carries the dye is not hardened, it gives its dye up quickly to the paper, and exactly corresponding to the luminosities of the print-plate. As a matter of fact, a pinatype print gives all the tonal values of the negative as well as a carbon print can do.

The practical details of pinatype are briefly as follows:—

(1) From the constituent negatives three transparencies are made on chloro-bromide or bromide lantern plates. If larger sizes are required, the negative must naturally be enlarged direct on to the transparency plates.

(2) The print-plates—that is, glass coated with thin gelatine—are sensitised in a $2\frac{1}{2}$ per cent. solution of bichromate, and when dry exposed under a transparency. The exposure can be determined with an actinometer.

(3) The exposed print-plates are washed, to remove the excess of bichromate, with cold water. The print-plate corresponding to the blue filter negative is dyed up in a solution of pinatype yellow, that corresponding to the green filter negative is dyed up with pinatype red, and that corresponding to the red filter negative is stained up with pinatype blue. The staining takes about fifteen minutes.

(4) A well-soaked piece of "transfer paper" is laid on the blue plate, which has been carefully washed with water, and after about ten minutes stripped. This blue image thus obtained is now laid in the same way on the red print-plate. The superposition is very easy, since the paper can be easily shifted on the plate, and can be distinctly seen through the print-plate. Finally the red + blue picture is laid in the same way on the yellow print-plate, and one has thus all three colors combined in the same film.

(5) The finished picture is simultaneously hardened and rendered perfectly stable to light by immersion in a "fixing bath."

2. If all three transparencies are to be made from the original negatives in the camera, the reversed positive can be very easily made by merely reversing the blue filter negative, that is to say, by presenting the glass to the lens. Obviously care must be taken that in all three exposures the distance from the negative film is the same. This is most easily attained if, for the exposures for the red and green filter negatives, a sheet of glass of the same thickness as the blue filter negative is laid in front of the film towards the lens.

The reversed positive obtained by one or other of these methods is now used in the ordinary way for making the yellow constituent transparency.

When the red + blue image is either cut or masked to

taste, the yellow image is provisionally placed thereon so that the outlines coincide; the corners of the red+blue transparency are then marked with a needle or the like, the yellow image cut to size, and the whole bound together in the usual way, after the outlines are made to accurately coincide.

It may be mentioned here that pinatype is very suitable for making monochrome pictures and transparencies in various colors. Duplicate negatives can be prepared much more easily by this than by any other method.

### Dr Selle's Process

Dr Selle uses the property of certain dyes which stain bichromated gelatine hardened by the action of light more strongly than the unhardened, and proceeds as follows:—"A sheet of glass is coated with a zinc-white collodion, which acts as the support for the colored picture. On this collodion film a bichromated gelatine film is coated, and when dry exposed under one of the negatives. By washing in cold water the undecomposed bichromate is removed from the gelatine film, whilst the chromic oxide formed by the action of light remains behind. The print is now laid in an aqueous solution of a mordant dye of corresponding color—that is to say, a dye which has the property of not staining pure gelatine, but of combining with the chromic oxide to form a so-called "color lake"; thus only those parts of the gelatine film which have been affected by light will be dyed. When dry, the first image is coated with collodion and a film of bichromated gelatine coated on top of it. On this light-sensitive film the second constituent negative is printed, after the outlines are made to accurately coincide with those of the first image. The second print is treated like the first, and stained in the proper color. Finally, after the second image has been coated with collodion, a third film of bichromated gelatine is coated on the top, and the third negative printed and dyed, etc. The finished print with the white collodion support may be easily stripped from the glass and mounted on a card."

The colors are very permanent, because they are chromium lakes; yet no dyes appear to exist which possess all the properties which Selle's process requires. This is the prin-

cipal reason why this interesting and really original process has not been introduced in practice.

A process founded on the principles of the Wiener-Neuhauss bleaching-out process has been patented by Szczepanik of Vienna for making prints from three constituent negatives.

Reichel of Munich makes three-color photograms by printing the three constituent negatives on collodio-chloride paper, tones them in special baths blue, red, and yellow, and then mounts them one on top of the other. For the red image a sulphocyanide gold bath with sodium iodide and potash is used; the yellow print is made by toning with lead, and the blue with iron salts.

As will be seen, there is a fairly wide choice of printing methods; but for practical work pinatype and the superimposed carbon tissues seem to be the best.

In order to complete the information, we must not omit a printing process which permits of the production of colored images by direct printing.

## Pinachromy

Certain dyes are converted by reduction into colorless substances, the so-called leucobases, which differ from the original body by the addition of two hydrogen atoms. O. Gros had already observed that these leucobases were sensitive to light—that is to say, that under the influence of light they were again converted into the original dyes by absorption of oxygen. The sensitiveness to light is, however, so low, and the colors formed so faint, that it is not possible to obtain practically useful pictures by means of the leucobases.

If, however, to the leucobases certain substances rich in nitrogen and oxygen be added, the sensitiveness to light is enormously increased, so that in a short time vigorous pictures may be obtained. Such substances are the nitric acid esters of polyatomic alcohols, such as nitro-glycerine and nitro-mannite.

For the preparation of colored pictures the process is as follows:—The leucobases are dissolved in collodion containing glycerine, and as the best sensitiser a little nitro-mannite is

added. However, the different leucobases require different sensitisers, in order to obtain the best results.

With such a mixture baryta paper is coated in the usual way, and exposed when dry under a negative. For making the blue print, for instance, ortho-amidotetraethyldiamidotriphenylmethane is used; for the red image, leucotetramethylrhodaminester; for the yellow image, leucoflavaniline.

It is most convenient to begin with the blue image, and it should be fixed as soon as it has attained the necessary intensity in a 10 per cent. solution of chloro-acetic acid, then washed and dried. A thin film of gelatine and chrome alum is then coated over it to isolate the film, and then the red leuco-collodion is poured on, again exposed under the green filter negative till the red image is sufficiently intense, and fixed; and then finally in the same way the yellow image is produced on the red and blue image.

The materials for pinachromy were produced commercially by the Hoechst Dye Works, but as the leuco solutions, especially the red, would not keep well, and the pictures left a good deal to be desired as regards stability to light, this process was soon displaced by Pinatype. Fuller details of the very interesting (scientifically) pinachrome process will be found in the *Photographische Mitteilungen*, 1904, p. 321.

### Two-Color Photography

A simple process for making color prints has been patented by Gurtner of Berne. It is not a three-color but a two-color process, which cannot, obviously, be claimed to give pictures true to nature, for the very reason that only two colors are used, yet on account of its simplicity is of no little interest, and as a matter of fact it often gives very beautiful effects in landscape work.

Gurtner makes with one simultaneous exposure the blue and yellow negatives, and dispenses with the red image, and cannot, therefore, reproduce red. Of the details of the process the following is practically all that is known:—A chlorobromide transparency plate is dyed for a few minutes in the dark in an aqueous solution of naphthol orange and dried. This plate is now placed film to film with a panchromatic plate, and the two placed in the dark slide so that the glass

of the transparency plate is presented to the lens. In focussing, care has, of course, to be taken to allow for the thickness of the glass of the first plate.

The orange-dyed transparency plate acts during exposure first as the sensitive plate for the blue rays, and secondly as a light-filter, which only permits the red, yellow, and green rays to reach the panchromatic plate. On the first plate there will thus be only the blue parts of the picture represented as black; on the second plate only the red, yellow, and green parts will be black. In other words, the transparency plate gives the negative for the yellow print, the panchromatic plate the negative for the blue print. The sensitiveness of the plates must be so adjusted that, during the long exposure required through the orange filter for the panchromatic plate, the transparency plate shall be correctly exposed. As, on account of the low sensitiveness of the latter, there is great latitude of exposure, this requirement is not difficult to fulfil. The negative on the panchromatic plate is generally slightly fuzzy—not on account of the minute difference of focus, but because the transparency plate, which acts also as a filter, diffuses the light like a screen of ground glass.

Special double-film plates for a similar two-color process have been made by Dr Smith of Zürich.

According to Gurtner, the prints are made as follows:—From the panchromatic (blue) plate, a Berlin blue print is made by any of the well-known methods, either by toning a transparency plate or bromide print or by printing on ferro-prussiate paper. The transparency (yellow) plate, from which the stain is quickly removed by fixing and washing, is either printed on P.O.P. or on stripping collodio-chloride paper. The prints should be fixed with ammonia without toning, and will thus acquire a muddy yellow or yellowish red tone. The yellow transparency is now directly combined with the blue, by placing the plates film to film. If a print on paper is required, the collodion print is transferred direct to the blue print. It is obvious, without further elaboration, that this process can never give us photographs in natural colors. Even if our eyes cannot directly recognise red in a landscape, yet in the multitude of compound colors red is always present. Moreover, the inventor admits that his process will not reproduce red. It would be wrong to

deprive the facts of their due importance, however, because of this defect. The results by two-color photography are very beautiful with suitably chosen subjects. In any case, Gurtner's process is the only one that works without a three-color camera, without filters, and without dyes, and which can be worked with the ordinary materials of the amateur photographer, and this fact ought to be sufficient to induce many to try it.

Quite recently Dr Smith of Zürich has produced commercially a plate with three films, which also contains the filters, for three-color photography. These plates are exposed in an ordinary camera, and give with one exposure all three negatives. Development is effected after the three films have been stripped from one another in the dark room. Whether these plates, which, on account of the difficulties of manufacture, are very dear, will prove of any practical value is an open question.

# PART II

## THE ADDITIVE METHODS OF THREE-COLOR PHOTOGRAPHY BY OPTICAL SYNTHESIS

Colored pictures are obtained by the previously described methods so that the three monochromatic pictures are superimposed, and thus all the compound colors of the original are formed.

It is possible, however, instead of actually combining the three monochromatic images so as to form a material image, to obtain the same result by reflecting or projecting the three monochromatic images so that they superimpose in our eyes. The methods which are used to attain this end are called "optical synthesis."

The results of color mixtures are here entirely different from those in three-color printing, for with optical synthesis we mix colored lights; in three-color printing we mix body colors or pigments. The results which are obtained by mixing pigments are known to all: thus red + yellow gives orange; red + blue, violet; and blue + yellow, green.

If we consider, for example, the formation of green, in a three-color print, by the superposition of the yellow and blue images: the blue film, which, for the sake of simplicity, we will assume to be evenly colored blue, transmits only green and blue light, and absorbs red and yellow; the yellow film transmits red, yellow, and green, and absorbs the blue. If now the two films are superimposed, they absorb together the whole of the incident white light except the green, which is common to both. There thus remains of the white light only green; the total amount of light is reduced, since each pigment takes away or "subtracts" something from the white light. If on top of the blue and yellow films a red one is laid, the green, and therefore all light, will be cut out. It is especially instructive to study this absorption or "sub-

traction" of light with a small pocket spectroscope, which is an indispensable adjunct for every three-color worker.

In a print, the compound colors are formed in the superimposed films exactly in the same way as in a transparency. The white light incident on the paper print penetrates the different colored pigment films, is reflected from the white paper, and again passes through the colored films, before it reaches our eyes. Thus there remains of the incident white light, in consequence of the absorption in the colored films, only a fraction, which is transmitted in common by the said pigment films.

On account of this reduction or "subtraction" of the incident or transmitted light by the individual constituent images, the processes of three-color photography described in the first section of this work are called "subtractive methods." In opposition to these there are processes in which three constituent images are combined by optical methods, and which are called "additive processes," as will now be explained.

Instead of, as before, passing white light through colored films, we will now consider the projection of colored lights on a white screen: using a triple projection apparatus with colored glasses before the light-sources. If a red glass is placed in front of a lens, the circular disc on the white screen will appear red, because nothing but the red rays will reach the white screen. By inserting a green glass in the second lantern, a green disc will be obtained; and now, as the screen reflects green and red light, it will appear yellow. Finally, by means of a blue glass and the third lantern a blue disc is projected. If this is allowed to fall on top of the yellow circle, all color will disappear and white will be the result.

When compound light, proceeding from a point, strikes our eyes, we cannot recognise the separate impressions. That white sunlight, for instance, consists of the so-called spectrum or rainbow colors is well known, though at the same time it conveys to our eyes only the impression of white. Our ears behave to sound quite differently: from a chord we can hear the separate tones and pick them out. The total effect of all the spectrum colors is not actually essential to give our eyes the impression of "white": two correctly chosen colors are quite enough, and these colors are then called complementary,

because they combine to form white. Complementary pairs of colors are, for instance:—

Red and blue-green.
Orange and cyan blue.
Yellow and reddish blue.
Greenish yellow and violet.

As, however, two colors cannot form all the compound colors which occur in nature, we must use, for the photographic reproduction of colors, three fundamental colors, which also, when correctly chosen, must produce the sensation of white.

From the following table drawn up by Helmholtz the result of the mixture of any two spectrum colors may be at once determined. The compound color will be found where the vertical and horizontal colors cut one another.

| | Violet | Indigo | Cyan Blue | Blue-green | Green | Greenish Yellow | Yellow |
|---|---|---|---|---|---|---|---|
| Red | Purple | D. crimson | W. crimson | White | W. yellow | Golden yellow | Orange |
| Orange | D. crimson | W. crimson | White | W. yellow | Yellow | Yellow | |
| Yellow | W. crimson | White | W. green | W. green | Greenish yellow | | |
| Greenish yellow | White | W. green | W. green | Green | | | |
| Green | W. blue | Water blue | Blue-green | | | | |
| Blue-green | Water blue | Water blue | | | | | |
| Cyan blue | Indigo | | | | | | |

D = dark.
W = whitish—that is, the color contains a lot of white.

Let us now return to the experiments with the lantern. On the screen is formed a white disc, as soon as the red, green, and blue circles are superimposed. This phenomenon is easily understood from what has already been stated. The sensation of white is caused by the fact that from every point of the circle green, red, and blue rays strike the eye. If now the blue is taken away, the mixture appears yellow, because our eyes recognise the want of blue as yellow. The following consideration is also very instructive: By means of interposed glasses only certain fractions of the white light fall on the projection screen; in our example the first circle only reflects

the red, the second the green, and the third the blue rays. If all three circles of light fall on the same place on the screen, all the colored rays which were previously reflected from different surfaces are now reflected from one, which therefore appears white to us. We have split up the white light by the colored glasses into three parts, and must therefore obtain the original white light again by addition of these three parts.

The expression " additive method " for the optical synthesis is now easy to comprehend. That is the fundamental difference between the subtractive and additive methods: in the former, by admixture of the fundamental colors black is formed, and in the latter white is formed.

On these fundamental principles are based the processes of color photography which are now to be described—which, however, as we have already pointed out, do not give a real material colored image, but the three constituent images are combined by optical means. Naturally, for the optical synthesis the three constituent images from which, in the subtractive method, the colored image is composed cannot be used; for, independent of other impossibilities, these pictures would represent black as white. On the places corresponding to black in the original the three constituent images are naturally deeply dyed, and from these intense colors, as we have seen above, white is formed by optical synthesis.

We must therefore start in quite another way to produce pictures by optical synthesis. Clerk-Maxwell, Ducos du Hauron, Ch. Cros, the pioneers of three-color photography, pointed out the possibility of combining the three constituent images into one picture in natural colors by optical means, but it was only through the work of Léon Vidal and Ives that the process was made practical.

The three constituent negatives have to be, as in three-color printing, made through three filters; yet the " additive " filters have not the same absorption as in three-color printing—in fact, they only absorb one color and transmit all the rest—but they split up the spectrum approximately into three parts.

The red filter only transmits red and yellow, and absorbs blue and green. The green filter transmits only yellow and green, and absorbs blue and red. The blue filter only transmits

blue, and absorbs red, green, and yellow. Since, as we have seen above, yellow can only be produced by optical synthesis by the mixture of red and green, yellow must act on the red and green negatives ; it must therefore be transmitted by the red and green filters. From the negatives taken through these filters an ordinary black-tone transparency is made on a bromide or chloro-bromide plate, in which only that must appear light which corresponds to the color of the filter. If now the negative taking filters are laid on the corresponding positives, and the images projected on a white screen, there appears on the red image only that which was red, yellow, or white in the original; on the green image, only that which was green, yellow, or white in the original; on the blue image, only that which was blue, violet, or white in the original. Black appears dark in all three pictures, so that on those particular places no light falls. If now the three colored images are superimposed on the screen, there will be formed a picture in natural colors, in which white is formed by the addition of the three fundamental colors.

Whilst thus in the subtractive process the three constituent prints are dyed with the colors complementary to the taking filter, in the additive process each constituent picture is colored by means of the colored light of the same color as the taking filter. This appears wonderful at first sight. For in the subtractive process only the shadows are dyed—that is to say, those parts of the positive which correspond to the transparent parts of the negatives, that is, those which are not affected by light ; in the additive process, on the other hand, the lights appear colored, which correspond to the black parts of the negatives.

In the ordinary method of printing a monochrome black image the process is practically the same as in the subtractive process : as, for example, in three-color work the positive image produced by green light is printed in the complementary color, red, so in the ordinary monochrome photography the image produced by white light is printed in a dark tone.

Instead of combining the three positives on a screen with a triple projection apparatus, the same result may be attained by the help of mirrors. Since only a few are in the happy position of possessing a costly and specially constructed triple

projection apparatus, we will give an accurate description of the mirror method. To F. E. Ives belongs the credit of having constructed an apparatus—first called a photo-chromoscope, and later a kromskop—on the principles here laid down. This apparatus was, some time ago, made by a special company, which, however, was not a success. The action of those chromoscopes was not specially good—on the one hand, because the technique of color photography was still in leading-strings; on the other hand, because the color-filters were unsuitable and absorbed too much light. More recently the chromoscope was considerably simplified by Zink of Gotha; and a similar instrument, constructed from the directions of Professor Miethe, has been placed on the market by Bermpohl of Berlin.

Before we proceed to describe the preparation of the pictures and the construction of the chromoscope, we must interpolate a few remarks.

When it was stated above the white was formed from red + green + blue, this strictly applies only to pure spectrum colors—that is to say, to colors which absorb all kinds of light except one, or, in other words, which only reflect one kind of light. Pigments of this kind do not exist; even the brilliant aniline dyes which appear so pure to us only fulfil these requirements in a very unsatisfactory manner. For instance, there exists no artificial or natural dye which only reflects or transmits the yellow rays. All yellow substances reflect also red, yellow, and green light. Therefore practically by the combination of three kinds of colored light an absolutely pure white cannot be obtained, but only a bright whitish tint. Fortunately, that does not matter much, as our eyes consider bright whitish spots as white when they are surrounded by brilliant saturated colors.

In spite of this minor fault, the pictures produced by the chromoscope far surpass in brilliancy of coloring, in delicacy and truthfulness to nature, all three-color transparencies. That the pictures are not actually colored, but only appear colored in the chromoscope, is advanced by many not unjustly as the reason why this method of color photography can never become popular. One might just as well call stereoscopic pictures valueless because they only give the effect of relief when examined in a stereoscope; or one might fall foul of transparencies because they are only seen in their full

beauty when projected. The chromoscope may find greater dissemination than the stereoscope or lantern, and much more easily than the latter; and it would be a desirable thing if this interesting apparatus could be placed sufficiently cheaply on the market, so that it might become more general. A new source of income would then be opened up to the professional photographer in the making of transparencies for the chromoscope, as the manufacture of such pictures in quantities presents no difficulties—for only the ordinary black transparencies are required.

The process of making the negatives for three-color printing and the chromoscope is the same; but whilst the difficulties and the minutiæ of three-color printing only begin in printing, for the optical synthesis method three ordinary contact positives are required. The chromoscope photographer need learn no new methods, need not dabble in dye solutions, nor need he laboriously make his own printing materials: the whole of his work is limited, as already stated, to the preparation of ordinary transparencies from the constituent negatives.

### The Taking Apparatus and Filters

All that was said on p. 24 applies also to the taking apparatus here; only the filters must be partially replaced by others. The apparatus recommended permits of the filters being changed in the simplest possible way, which, for those who practise both methods, will be found very convenient.

The general remarks on the preparation of the light-filters on p. 29 apply obviously also to the additive filters.

The blue filter used for the subtractive method may be successfully used, for it is so dark that it only transmits the extreme red of the least refrangible rays. These do not act on the modern panchromatic plates with the short exposures required for the blue rays. To make an additive blue filter, dissolve as described on p. 32—

| | | |
|---|---|---|
| Crystal violet . . . . . | 46 grs., | 3 g. |
| Methylene blue (free from zinc chloride) . . . . | 15½ „ | 1 g. |
| Water . . . . . . | 3½ ozs. | 100 c.cs. |
| Glacial acetic acid . . . | 5–6 drops. | |

To every 100 parts of a 6 per cent. solution of gelatine should be added 8 parts of the above dye solution, and to every 16 square inches (100 qcm.) of glass should be allowed 118 minims (7 c.cs.) of the filtered dyed gelatine. The filter is composed of two such glasses cemented together.

The additive green filter should only transmit green and yellow, and absorb red and blue. To make the dyed gelatine, dissolve—

| | | |
|---|---|---|
| Tartrazine . . . | 92½ grs., | 6 g. |
| Patent blue . . . . | 15½ „ | 1 g. |
| Hot water . . . . | 4 ozs. 445 m., | 140 c.cs. |

To every 100 parts of 6 per cent. gelatine solution should be added 7 to 8 parts of the above dye solution, and the mixture carefully filtered. To every 16 square inches (100 qcm.) of glass should be allowed 118 minims (7 c.cs.) of dye solution To make the filter, two such plates should be cemented together.

This green filter transmits some of the extreme red end of the spectrum, but this does no harm.[1] This red can also be absorbed by the addition of some naphthol green; but then the filter, in consequence of the deep tint, requires a longer exposure. To make such a filter, dissolve—

| | | |
|---|---|---|
| Naphthol green . . . | 31 grs., | 2 g. |
| Patent blue . . . . | 15½ „ | 1 g. |
| Tartrazine . . . . | 93 „ | 6 g. |
| Hot water . . . . | 6 ozs. 160 m., | 180 c.cs. |

To every 100 parts of 6 per cent. gelatine solution should be added 8 to 9 parts of dye solution. To every 16 square inches (100 qcm.) should be allowed 118 minims (7 c.cs.) of dyed gelatine.

This filter dampens the extreme red very strongly: if the whole of the red is to be absorbed, the filter would be so dark as to require enormously long exposures.

The same result—that is to say, the almost complete absorption of the extreme red—is obtained by the use of the new filter green II. of the Hoechst Dye Works. Of this dye 62 grains (4 g.) should be dissolved in 4 ozs. 107 minims (120 c.cs.) of water, and 6 to 7 parts of the dye solution added to 100 parts of 6 per cent. solution of gelatine.

[1] See p. 33.

Especially transparent and bright filters can be made by use of the rapid filter green II.; this filter transmits, however, a comparatively large amount of red, but this is quite harmless.

According to Dr König's experience, it is not advantageous to damp the yellow by a greater addition of blue. The green then, in consequence of the exposure, which is unduly lengthened by the darkness of the filter, acts too strongly, and will be reproduced in the positive too bright, so that the green in the picture will be too brilliant and will appear unnatural.

Green, the correct reproduction of which frequently presents many difficulties, can be much better reproduced by the additive method. In three-color printing the green often appears brownish, because the green filter negative is not sufficiently dense in the required places; so that, in the green, too much red is printed. If, on the other hand, in the additive process the green filter negative is not sufficiently dense in the green, the green in the transparency, and therefore in the colored picture in the chromoscope, will at the worst appear a little too dark, but never appear wrong in color.

The red filter should only transmit red and yellow, and absorb completely green and blue. This is made by dissolving—

| | | |
|---|---|---|
| Tartrazine . . . . | 62 grs., | 4 g. |
| Rose Bengal . . . | 54 „ | 3·5 g. |
| Water . . . . | 5 ozs. 134 m., | 150 c.cs. |

To every 100 parts of 6 per cent. gelatine solution 7 to 8 parts of this dye solution should be added, and to every 16 square inches (100 qcm.) should be allowed 118 minims (7 c.cs.) of the dyed gelatine.

Instead of this additive red filter a subtractive filter may be used, and the only difference is that there is rather less absorption in the yellow-green in the latter. From this it is obvious that it is only the additive green filter which essentially differs from the subtractive one.

The cementing of the filters with Canada balsam is effected in exactly the same way as indicated on p. 34. All that has been said with regard to the plates (p. 35) also applies.

The relative times of exposure with pinachrome-bathed plates is approximately—

| | | |
|---|---|---|
| For the blue filter | . . | 1 |
| „ green „ | . . | 5 |
| „ rapid green filter | . | 3 |
| „ red filter | . . . | 3–4 |

The exact estimation of the ratio of exposures is effected in precisely the same way as described for the subtractive methods on p. 44.

The constituent negatives should answer to the following requirements:—

1. On the blue negative, blue and violet should be dense; scarlet-red, yellow, and green should be clear glass.
2. On the green negative, green and yellow should be dense, red and blue be clear glass.
3. On the red negative, red and yellow should be dense, blue and blueish green be clear glass.

A blueish red should also be a half-tone on the blue negative; a yellowish green should be a half-tone on the red negative. White should obviously be very dense on all three negatives, and black clear glass on all three.

The negatives should be fairly vigorous and clean, but rather too soft than too hard. Experience will soon teach exactly the character of negative to give good transparencies.

### Printing from the Constituent Negatives

For making the transparencies, plates and developer should be chosen which will give pure black tones. The transparencies should be vigorous and clean, but not hard. If they are too flat, the darkest places, through which no light should penetrate at all, appear somewhat transparent and produce false lights in the picture, which disturbs the colors and makes them whitish. If, on the other hand, they are too hard, the colors are extraordinarily brilliant, unnaturally bright, and the light parts show no details. Only experience can teach us the exact kind of transparency to make, but this experience is very quickly and easily gained.

Development of the transparencies should be continued till the high lights show the details. If this is not reached

before the rest of the image is too dark, the transparency has been under-exposed or the negative is too hard. In the latter case ammonium persulphate should be used to reduce the negative. If the high lights of the transparency appear too dense, before the rest of the picture is sufficiently dense, the exposure has been too long or the negative is flat.

If the character of the three constituent negatives is different, it is not of such moment with the additive process as with the subtractive, as these differences may be compensated for in making the three transparencies; and this is easy for those who have some experience in transparency-making. Thus, for hard negatives the exposure should be full and a dilute developer used; for flat negatives, on the other hand, a hard working concentrated developer should be used, with the addition of bromide.

It is quite unnecessary for us to give specific developing formulæ, for satisfactory results may be obtained with any good developer; and naturally the best to use is that to which the operator is accustomed.

Transparencies which are too flat—which, as we have already seen, give dull whitish colors—may be improved by intensification. Incorrect exposure and development of the transparencies do not influence the rendering of the colors, nor the shades, only the intensity of the picture. The colors, assuming that the negatives are good, will be almost always good as regards tint, but frequently bad in their intensity.

If only one plate is used for the negatives, naturally the transparencies may also be made on one plate and simultaneously developed, and then cut afterwards.

The statement advanced by many writers, that one ought not to intensify or reduce plates intended for color photography, cannot be supported by the authors. Obviously, in color work as in ordinary monochrome photography every exposure will not be a success. If, however, the faults in exposure and development are not too great, faultless and beautiful pictures may be attained by reasonable correction of the negatives and positives.

Color photography is not a purely mechanical copying of nature, carried out with mathematical precision, and that, indeed, it will never be. He who works quite automatically will never advance.

The finished transparencies should be marked with the letters B., Y., R. (blue, yellow, red), so as to distinguish them.

### The Observing Apparatus

The three constituent images can, as has been already pointed out, be projected by means of a triple lantern, or be combined into one colored picture by means of the photochromoscope. As a triple lantern is very costly, and therefore limited in use, we will describe the construction of a chromoscope. They may be obtained commercially, but at

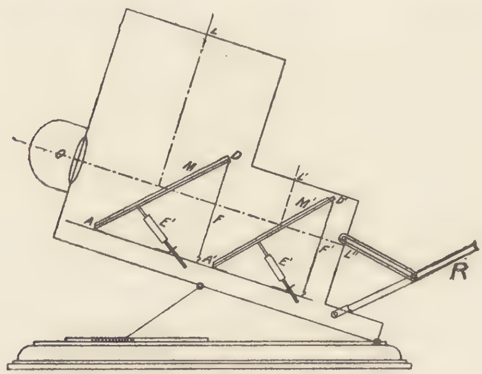



Fig. 3. Section of Chromoscope.

a rather high price. We will therefore accurately describe the construction of such an apparatus, so that everyone with a few tools may be able to make one, and one that will be as efficient as a bought one.

The principle of the chromoscope can be most easily explained from the accompanying diagram (fig. 3). The box made like steps has apertures at L, L′, and L″ for the light-filters. In the inside are two transparent mirrors, M and M′, which are fixed at an angle of 45° to the bottom of the box. R is an ordinary mirror or a white card, and is used to illuminate the light-filter at L″. On the filters the transparencies are placed. The eye which is placed at O sees the transparency at L″ through the mirrors M and M′. The picture at L′ is reflected by the mirror M′ and passes through M to the eye O. The picture at L is reflected by the mirror M

to the eye at O. By means of the mirrors M and M′, which are inclined at an angle of 45°, the pictures, which are lying in a horizontal position at L and L′, are seen in an inverted and upright position at L″. The measurements of the apparatus are so adjusted that the mirror-images of L and L′ combine with L″.

As is well known, the mirrored image of an object appears to be as far behind the mirror as the object itself is in front of the mirror. Therefore must LM = ML″ and L′M′ = M′L″. From this it follows that LM − L′M′ = ML″ − M′L″, or the distance of the mirrors M and M′ from one another must be equal to the distance of L and L′.

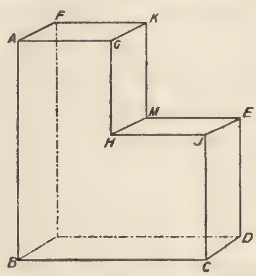



Fig. 4. Diagram of Chromoscope: letters agree with table of measurements, below.

The wood may be any well-dried sort, about two-fifths of an inch (1 cm.) thick, which will not warp.

For 9 × 12 cm. pictures the measurements should be kept to about the following:—

*Outside Measurement.*

| | | | | Millimetres. | Inches. |
|---|---|---|---|---|---|
| AB | | = | | 285 | $11\frac{1}{5}$ |
| CD | = | AF | = | 165 | $6\frac{1}{2}$ |
| BC | | = | | 265 | $10\frac{2}{5}$ |
| AG | | = | | 135 | $5\frac{3}{5}$ |
| HG | | = | | 125 | $4\frac{9}{10}$ |
| CJ | | = | | 160 | $6\frac{3}{10}$ |
| HJ | | = | | 130 | $5\frac{1}{10}$ |

The horizontal surfaces AGKF and HJEM have exactly in the middle an aperture of about 10 × 13 cm.; the vertical surface CDEJ has an aperture of the same size, the upper edge of which is exactly so far from JE as the nearest edge of the aperture HJEM is from JE. One side-wall ABCJHG carries a flap which is provided with hinges and turn-buckle, which is just so large that the mirror which will be mentioned later, with the boards that carry it, can be conveniently stowed away in the apparatus.

On a board of exactly the size of the inner bottom surface of the apparatus the two previously mentioned transparent mirrors M and M′ (fig. 3) are fastened in the following manner :—The mirrors, which should measure about $135 \times 135$ mm., are placed with their lower edges on two metal angle plates *a* and *a′* which should be screwed to the board, and the shorter side of which should slant about 5 mm. above the board. The longer side should have a slit about 25 mm. long, through which passes the binding-screw. This slit enables one to shift the metal plate if required. The mirror is supported behind by the screws C and C′, by means of which it can be inclined more or less. It is best for these screws to be upright to the surface of the mirror which is at an angle of 45°, and they should therefore form that angle with the bottom of the box. In order to give the mirrors the necessary support, they should have on their upper edge a narrow metal edging *d* and *d′*, to the ends of which should be soldered a hard brass or steel spring *f* and *f′*, which may be hooked to small loops fastened for this purpose to the base-board.

The distance of the two mirrors from one another is, as already mentioned, the same as GH (fig. 4) = 125 mm. ($4\frac{9}{10}$ in.). The rear mirror should almost touch the back wall CDEJ with its metal edging. The image which is found at L″ (fig. 3) should be illuminated by a mirror or, better still, a sheet of opal glass provided with hinges. The whole apparatus should be finally fastened to a stout board by hinges, as at CD (fig. 4), so that it may be directed to the sky and fixed in any desired position, as shown in fig. 3.

A piece should be cut out of the front wall ABF, and be again fastened in with screws and turn-buckles. In this cut-out piece should be fastened an ordinary biconvex lens of 35–40 cm. (12–16 ins.) focus, so that its optical axis will pass through about the middle of the aperture CDEJ. This lens need not be achromatic: one of the ordinary so-called reading lenses, which can be obtained from any optician for a few pence, will answer perfectly. As large a lens as possible should be chosen, so that both eyes may be used at once: above and below the lens should be blocked out with black paper, so that only a horizontal slit remains for the eyes to look through. The inside of the chromoscope

and the boards which carry the mirrors should be carefully painted dead black. A thin alcoholic solution of shellac mixed with enough lamp-black to give it a dead appearance may be used.

### Making the Filters for the Chromoscope

For the filters of this observing apparatus, plate-glass need not be used; ordinary flat glass, free from bubbles, which can be cut from old dry plates, may be used. They need not be cemented with Canada balsam, though two colored screens should be used, placed film to film, for each filter, to secure even staining.

*The Blue Filter.*

| | | |
|---|---|---|
| Crystal violet . . . | 46 grs. | 3 g. |
| Methylene blue . . . | 15½ „ | 1 g. |
| Glacial acetic acid . . | 5–6 drops, | 5–6 drops. |
| Warm water . . . | 3½ ozs., | 100 c.cs. |

To every 100 parts of 6 per cent. gelatine solution should be added 2–3 parts of the dye solution, and the mixture filtered; and to every 200 square inches (130 qcm.) of glass should be allowed 168 minims (10 c.cs.) of the dyed gelatine.

*The Green Filter.*

In this case also, the green filter is the only one which presents any trouble. It is advisable, therefore, to make five or six filters of various intensities, and then to choose the best.

| | | |
|---|---|---|
| Tartrazine . . . . | 93 grs. | 6 g. |
| Patent blue . . . . | 15½ „ | 1 g. |
| Naphthol green . . . . | 31 „ | 2 g. |
| Warm water . . . | 6 ozs. 160 m., | 180 c.cs. |

To every 100 parts of 6 per cent. gelatine solution should be added 2·5–3·5 parts of the dye solution. To every 200 square inches (130 qcm.) of glass should be allowed 115–230 minims (8–16 c.cs.) of the dyed gelatine, so as to obtain filters of different intensities. Obviously, also, different quantities of the dye solution may be added to the gelatine solution, and thus the same amount of gelatine solution be allowed for each filter.

*The Red Filter.*

| | | |
|---|---|---|
| Tartrazine . . . . | 62 grs. | 4 g. |
| Rose Bengal . . . . | 54 „ | 3·5 g. |
| Water . . . . | 5 ozs. 134 m., | 150 c.cs. |

To every 100 parts of 6 per cent. gelatine solution 4–5 parts of the dye solution should be added and filtered, and to every 200 square inches (130 qcm.) should be allowed 168 minims (10 c.cs.) of dyed gelatine.

### The Mirrors

As the mirrors M and M′ (fig. 3) must not only reflect the images at L and L′, but also transmit the image from L″, ordinary mercury mirrors are not available. On the other hand, silvered or platinised glasses may be used, which have such a thin metallic coating that they are sufficiently transparent. The disadvantage of these mirrors is that they are very difficult to obtain, and easily spoilt, and that their brown or grey color, when looked through, to some extent spoils the color of the picture. Ordinary uncoated plate-glass cannot be used, as it reflects too little.

It is best to use plate-glass, colored in the mass, and which is fairly bright, for the chromoscope mirrors, as they not only reflect strongly, but are also very transparent, and a secondary image from the back surface is not seen, as we shall see later.

Now the filters should be temporarily fastened in the apertures of the box, and at L (fig. 3), the red; at L′, the blue; and at L″, the green filter—each consisting of two dyed glasses.

The mirror M′ should now reflect the blue picture from L′, and the green picture from L″ transmit unweakened; therefore for this mirror a green glass should be chosen as near the tint of the green filter at L″ as possible. The mirror M should reflect the red picture at L, and also transmit undimmed the green picture at L″ and also the blue picture at L′; therefore for this mirror a greenish-blue glass should be chosen, which transmits blue and green rays.

It is well known, however, that any ordinary mirror gives two images—the one, and the more distinct, which is given by the coated back surface of the glass, and the other and fainter

which is formed by reflection from the front of the glass. This secondary reflected image, which blurs the primary one, cannot be formed by the arrangement just described. The blue light which falls on the mirror M′ will be strongly reflected from the upper surface, but will, before it can reach the back of the mirror, be so weakened by the green glass that after reflection from the back of the glass and again passing through the green glass it is completely absorbed, so that only the reflection from the front surface of the glass comes into play. Exactly the same takes place with the blue mirror M: a reflection of the red image from the back of the mirror is completely excluded, because the red light, by passing twice through the blue glass, is completely absorbed.

One might expect that mirrors of colorless glass with a coating of dyed gelatine would be useless for the chromoscope, on account of this double reflection. But this is not so: with such glasses as sharp and as beautiful pictures may be obtained as with mirrors made of glass colored in the mass,[1] so that one may dispense with these and prepare for oneself suitable mirrors. Dr König, indeed, recommends these home-made mirrors in preference to the colored glass ones, because the latter are extremely difficult to obtain of the correct tint; the green glass is generally cloudy, and the blue almost always of a red tint rather than greenish, so that the results are much better with home-made mirrors which are spectroscopically correct. The preparation of these filters is very easy: thin white patent plate, glass of 135 × 135 mm. is coated with the dyed gelatine as described on p. 85, and after drying should be cemented to a sheet of plain glass with Canada balsam.

*The dyed gelatine for the green mirror.*

| | | |
|---|---|---|
| Tartrazine . . . | 8 grs., | 0·5 g. |
| Naphthol green . . | 12½ „ | 0·8 g. |
| Patent blue . . | 18½ „ | 1·2 g. |
| Water . . . | 8 ozs. 384 m., | 250 c.cs. |

To every 100 parts of 6 per cent. gelatine solution should be

[1] The secondary image is in consequence of the absorption so weak that it cannot be perceived in the brilliant primary image.

added 8 parts of the above dye solution, and the mixture filtered. For a screen $135 \times 135$ mm. should be allowed 13 c.cm. of the dyed gelatine.

*The dyed gelatine for the blue mirror.*

| | | |
|---|---|---|
| Patent blue . . . . | $15\frac{1}{2}$ grs., | 1 g. |
| Warm water . . . . | $3\frac{1}{2}$ ozs., | 100 c.cs. |

To 100 parts of 6 per cent. gelatine solution should be added 4 parts of the dye solution, and the mixture filtered. To $135 \times 135$ mm. should be allowed 13 cm. of dyed gelatine.

The colored mirrors should now be fastened in position, as previously described on p. 84, on the boards, with which they should make an angle of 45°. Under the blue filter should be the green mirror; under the red filter should be the blue mirror.

The chromoscope should now be slanted towards the bright sky, so that the light can fall full and unhindered on the color-filters. The lens should now be looked through, and the inclination of the two colored mirrors should now be altered by means of the screws, till the images of the filter apertures coincide as far as possible: narrow colored fringes to the field of view will not be troublesome. The field of view should, if the filters are in accord, be whitish and very bright. If it is distinctly reddish or greenish, the green filter is not correct. With a red field of view the green filter is too dark; with a greenish field it is too bright. The green filter should then be changed for another, till as pure a white as possible is obtained. If the field is yellowish, the blue filter is too dark; if it is blue, the red filter is too dark or the blue filter too bright.

If the filters and mirrors are accurately prepared according to the above formulæ, it will generally be only the green filter which must be changed. An absolutely pure white, as has been pointed out, in spite of advances in the manufacture of our colors, will never be obtained, and one must therefore be content with as bright a whitish tint as one can obtain.

When the best filters have been chosen, they should be fixed, gelatine sides together, by strips of paper definitely in the apertures. To hold the positives at L″ (fig. 4) two wooden or metal grooves should be provided, in which the

transparencies may be inserted. At L′ and L it is simplest to use the spring metal strips, which will hold the transparencies in position and yet permit of a little shifting of the same if this is necessary.

In front of the green filter L″ the transparency which corresponds to the green filter negative is placed; on the red filter is placed the positive corresponding to the red filter negative. The blue filter should be temporarily covered with a piece of card or other opaque material. As the green image is immovably fixed in its frame, the red transparency is shifted till the two pictures absolutely coincide. Then the card should be removed which covered the blue picture, and then this placed in position in the same way.

The pictures are extraordinarily brilliant in coloring, of great translucency, and, if negatives and positives are correctly made, startlingly true to nature. The effect of stereoscopic pictures is also most wonderful, for the action of the colors is backed up by the plastic effect.

If the measurements of the chromoscope are not exact, it may happen that the three images may coincide, but do not lie in the same plane; for instance, the red image may be in front of or behind the green. If the red mirror image is in front of the green transparency, the distance LM (fig. 3) is too small; if it lies behind, LM is too great. This may be remedied either by shifting the mirror M backwards or forwards, or by altering the distance LM (fig. 3) or GH (fig. 4). It is as well to bear in mind the possibility of this happening when making the instrument, and to arrange so that the heights GH and CJ may be slightly altered by inserting a wooden frame or planing a little off. This regulating of the apparatus need only be done once, whilst the transparencies require to be focussed each time. This focussing is not at all difficult, and with a little experience may be very quickly done. Micrometer screws and so on for the fine focussing of the images are quite superfluous, and only unnecessarily complicate the apparatus. Above all things, for the adjustment of the pictures a steady hand is required. The simplest method of setting to work, in order to avoid adjusting it each time, is as follows:—

The red and blue transparencies should be provided with narrow card margins, which should be stuck on. On the

edges GK and JE (fig. 4) of the chromoscope should be fastened a T-square of wood or metal, only a few millimetres large, against which the picture with its edge should be laid. It is now easy by careful and gradual cutting away of the card to so arrange the transparencies that they will exactly coincide. Subsequently it will only be necessary to always press them up against the T-square to at once obtain immediate coincidence of the three pictures. Naturally, the mirrors must remain in their places. The slightest change in the positions of the mirrors M and M′ will cause the pictures not to coincide, and they must be again adjusted.

Chromoscope pictures which for some reason are not quite correct, and show, for instance, a prevailing greenish tone, may be often improved in an astonishing manner by placing over the green transparency a very pale green glass. It is advisable to prepare several such glasses of various intensities by coating glass with the mixture recommended on p. 85 for the green mirror, using rather smaller quantities of dye.

The same method should be adopted if in dull, cloudy weather the field of view of the chromoscope does not appear white, but strongly colored. By the insertion of a suitably chosen slightly colored filter again obtain white, but of course at the cost of some brilliancy of the image. The chromoscope is thus an instrument by means of which we may test whether the composition of the daylight is normal or not, which is under certain circumstances of great importance for three-color work (compare p. 44). It is, of course, naturally assumed that with a bright clear sky the chromoscope gives white.

Only the electric arc and magnesium light, amongst artificial lights, can be used for examining chromoscope pictures. Incandescent gas and electric lights are not suitable, as they both contain too little blue. Therefore with these lights white can never be obtained, and it will be noted that the blue picture may be taken out or inserted without any marked alteration in the effect.

The chromoscope may be used not only for the synthesis of three-color pictures, but is also a very interesting scientific toy. Above all things, the laws of the mixtures of colors may be accurately studied, and at the same time it permits

of some very beautiful experiments being performed. If, for instance, two of the constituent images are misplaced, they can naturally be made to coincide, but absolutely false colors will be obtained, which are often very striking and original. Instead of using transparencies, the negatives may be placed in the chromoscope, and a picture will be obtained in which white will appear black, and all colored objects will appear in their complementary colours. Thus, green roses with red leaves, blue strawberries may be produced as if by magic; colors and color combinations will appear which even the most florid phantasy of a secessionist painter could not imagine. Léon Vidal, in his work, *Traité pratique de Photochromie*, lays great stress on these experiments, and justly recommends the chromoscope to all artists and manufacturers who have to deal with color: the painter, printer, decorator, paper, cloth, and carpet manufacturers, would find it useful, and the chromoscope would simplify the discovery of new harmonious color combinations and patterns. For the three-color photographer the chromoscope is quite indispensable, for it enables him to judge as to the suitability of his negatives or positives before he goes to the trouble of printing.

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If, in conclusion, we endeavour to form any opinion as to the position of color photography from the practical standpoint, the result will be practically as follows:—

For making prints on paper, the methods of superimposed carbon prints and pinatype are the most satisfactory.

Transparencies are easier to make, and either Sanger-Shepherd's process or pinatype seems the best.

For two-colored pictures, the only process is Gurtner's.

Chromoscope pictures are the easiest to make. The reproduction of the colors is better than with three-color printing; success is more certain than with other methods. The preparation of the pictures requires but little time, and requires neither special dye solutions nor chemicals, nor learning new methods of working.

How few know the chromoscope, and how easy it is to use this apparatus! The chromoscope photographer has not to battle with the difficulties, and does not experience the disappointments, with which the three-color photographer

has to reckon. As a matter of fact, up to the present chromoscope photography is that method which can be most strongly recommended to those who may wish to take up three-color work as a hobby, without giving up too much time to the same.

If, since the first edition of this book, considerable advances have been made in color photography, the new methods are, for the average amateur who is only accustomed to work P.O.P., and also for the greater proportion of professional photographers, still far too troublesome; and thus three-color photography, although it has undoubtedly a much greater following than heretofore, can only reckon on a comparatively small following amongst beginners.

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